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INSTRUCTION MANUAL

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131-38 SANFORD AVE. • FLUSHING, N.Y. 11352
(212) 461-7000 • TWX #710-582-2631

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KS

REGULATED DC SUPPLY

design group

Model KS 120–1 (M)

Serial No. H-62066

INSTRUCTION MANUAL

The KEPCO equipment described in this instruction manual is of proprietary design, covered by one or more of the following United States patents and/or by other (U.S. and Foreign) Patents or patents pending.

2,992,379	3,112,439	3,241,042	3,275,948
2,992,386	3,128,423	3,243,690	3,303,411
3,028,538	3,131,344	3,243,749	3,303,412
3,056,905	3,210,619	3,275,925	3,303,415
3,088,053	3,226,628	3,275,927	3,305,763
3,092,757	3,241,054		

Canadian Patents: 733629 – 736084
Australian Patents: 263,835 – 264,975

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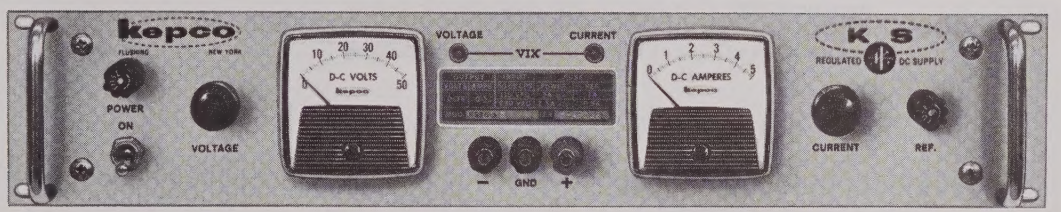


FIG. 1-1 KS POWER SUPPLY, TYPICAL FRONT VIEW

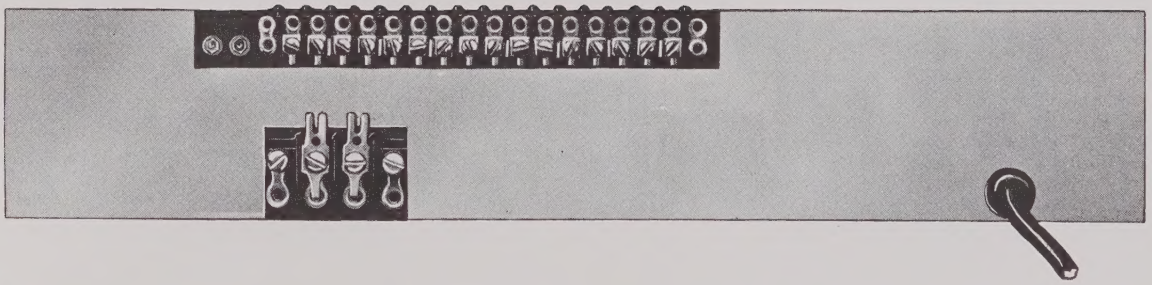


FIG. 1-2 KS SERIES POWER SUPPLY, REAR VIEW (TYPICAL)

SECTION I - INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This instruction manual contains information for the installation, operation, and maintenance of the KEPCO Series KS regulated power supplies.

1-3 GENERAL DESCRIPTION (Refer to FIG.'s 1-1 and 1-2)

1-4 The KEPCO KS Design Group consists of a series of precision regulated, highly efficient power supplies whose specifications and electrical characteristics are identical, except as noted in table 1-1. Phase controlled silicon controlled rectifiers in conjunction with a feedback regulating system provide the output power. High resolution controls in the voltage and current regulating modes are provided. Automatic crossover between the two operating modes is indicated by front panel lights. The rear barrier strip provides for the convenient access to the circuitry for the purpose of remote programming or system integration. Heavy duty rear output terminals for load connection are provided. Built-in forced air cooling with lateral circulation provides adequate ventilation for continuous operation at any output within the specified range.

1-5 The Power Supply chassis and case are constructed of plated cold rolled steel throughout. The front panel is heavy gauge aluminum finished in Light gray Federal Std. 595, Color #26440, unless otherwise specified, and equipped with chrome plated carrying handles.

1-6 The major part of the circuitry is on plug-in type printed circuit boards, and can be conveniently disassembled for maintenance purposes. All power transistors are installed into plug-in type assemblies, especially important for periodic maintenance checks.

1-7 SPECIFICATIONS, GENERAL

a) Input Requirements: 105 VAC to 125 VAC or 210 VAC to 250 VAC, 50 cps to 65 cps, single phase
For maximum input current see table 1-1.

b) Ambient Operating Temperature: -20°C to +50°C.

c) Storage Temperature: -40°C to +85°C.

d) Isolation Voltage: Maximum output voltage plus 500V DC between chassis and either output terminal.

1-8 SPECIFICATIONS, GENERAL PERFORMANCE

a) Controls: Continuously adjustable 10-turn voltage and current controls permit output settings from zero to the maximum voltage and current. Resolution: 0.05% of maximum output.

b) Programming: Special terminals provide for remote resistive programming of voltage or current at 100 ohms per volt. Programming terminals are also provided for programming by means of remotely located voltage or current signals.

c) Automatic Crossover: The automatic crossover circuit switches the operating mode of the power supply automatically from constant voltage to constant current or vice versa depending on the load relationship to the panel voltage and current adjustments. In the voltage regulation mode, the current control serves as a current limit adjustment while in current regulating mode, the voltage control serves as a voltage limiting adjustment.

d) VIX Indicators: The power supply's operating mode is indicated by a pair of front-panel signal lamps. One lamp is lighted during voltage regulated operation, the other during current regulated operation (internal current sensing only). Crossover from one mode to the other is signalled by the extinction of one lamp and the lighting of the other.

e) VIX Remote Signal: A pair of rear-panel pin jacks, labelled "V" and "I" provide external access to the VIX signal. Pin V is 8 volts positive with respect to pin I during voltage regulated operation. Pin I is 8 volts positive with respect to pin V during current regulated operation. Maximum loading: 10 K ohms; isolated from ground and the output terminals of the power supply. Crossover from one mode to the other is signalled by an abrupt polarity reversal.

f) Remote Error Sensing: Error sensing terminals enable specified voltage regulation to be maintained directly at the load by compensating for voltage drops up to 0.5 volts across each load supply lead.

g) Series/Parallel Operation: Automatic crossover capability permits series or parallel operation in either voltage or current regulating modes. Units operate automatically to share a load by means of their automatic crossover feature. Connections are also provided for operation in master/slave configuration.

h) Cooling: Lateral circulation by blowers insures efficient heat transfer; permits stacking of multiple units without overheating.

i) No Voltage Overshoot: No output voltage overshoot from turn-on, turn-off or power failure for output settings above 25% of maximum rated voltage. Below 25%, output overshoot is a function of load and is negligible for loads in excess of 10%.

1-9 SPECIFICATIONS, VOLTAGE REGULATION MODE

a) Regulation:

1) Line: Less than .005% output voltage change for 105-125V AC or 210-250V AC line variation, at any output voltage within the specified range.

2) Load: Less than 0.01% or 0.5 mv output voltage change, whichever is greater, for no load to full load change at any output voltage within the specified range.

b) Stability: Output voltage varies less than 0.01% or 3 mv, whichever is greater, over a period of 8 hours after warmup. Measured at constant line voltage, load and ambient temperature.

c) Temperature Coefficient: Output voltage changes less than 0.01% per °C.

d) Ripple: Less than 1 mv rms.

e) Recovery Time: 50 microseconds.

f) Output Impedance: Specified for each model within the load frequency range shown in Table 1-1. Above 10 kc include the reactive impedance of the effective series inductance as indicated.

1-10 SPECIFICATIONS, CURRENT REGULATION MODE

a) Output Range:

1) Internal Sensing: Current regulation from less than 0.5% to 100% of the maximum specified current. Automatic crossover to voltage limiting provided.

2) External Sensing: Current regulation from 10 ma to 100% of the maximum rated current.

b) Compliance:

1) Internal Sensing: Voltage compliance range is zero to the voltage control setting. The setting is adjustable, zero to 100% of the rated voltage range.

2) External Sensing: Voltage compliance is zero to 100% of the maximum output voltage.

For any selected current value, the output voltage is automatically varied throughout the compliance range as required to regulate the output current through a variable load.

c) Regulation, Internal Sensing:

1) Line: Less than 0.01% or 1 ma, whichever is greater, output current change for 105-125V AC or 210-250V AC line variation at any output current within the specified range. For models rated at 10 amperes or less output current, the 1 ma regulation specification governs.

2) Load: Less than 0.01% or 1 ma, whichever is greater, output current change for the maximum change in load resistance within the rated compliance range. For models rated at 10 amperes or less output current, the 1 ma regulation specifications governs.

d) Regulation, External Sensing:

1) Line: For 105-125V AC or 210-250V AC line variations, output current changes less than 0.01% when the specified voltage sample is maintained across the external sensing resistor.

2) Load: For the maximum change in load resistance, within the rated compliance range, output current changes less than 0.01% when the specified voltage sample is maintained across the external sensing resistor.

The sensing resistor is chosen to produce a one volt drop at the maximum operating current. A separate control is used externally to provide high resolution current adjustability.

e) Stability: Output current varies less than 0.05% or 5 ma, whichever is greater, over a period of 8 hours after warmup. Measured at constant line voltage, load and ambient temperature.

f) Temperature Coefficient: Output current changes less than 0.05% per °C.

g) Ripple: Less than 0.1% of output current setting or 0.05% of maximum current rating, whichever is greater, rms.

1-11 SPECIFICATIONS, PHYSICAL

a) Meters: Model numbers in table 1-1 include 2 1/2", rectangular voltmeter and ammeter; 2% full scale accuracy. Unmetered units have the suffix "M" deleted from the model number.

b) Terminals and Controls:

1) On Front Panel: AC on-off switch, circuit breaker/fuse and two VIX mode lamps. 10-turn voltage control, 10-turn current control, reference circuit fuse, DC output and ground terminals (8 3/4" models have output terminals on the rear only).

2) On Rear of Chassis: Two VIX remote signal 0.08" pin jacks. Barrier strip connections for: remote error sensing, voltage and current programming by remote resistance and/or voltage, master-slave, parallel operation, external current sensing. DC output and ground terminals. Output terminals are isolated from the chassis, either positive or negative terminal may be grounded.

c) Dimensions: Standard EIA rack dimensions. Refer to FIG. 1-3.

d) Finish: Light gray Federal Std. 595, Color #26440. (Special finishes to order).

1-12 ACCESSORIES

1-13 Accessory equipment for this power supply is available (but not supplied) to increase its range of applications.

a) VIX-1 Relay, translates the VIX remote signal, available at two connectors in the rear of the unit, into a heavy duty relay closure for external signal applications.

b) KP-10 PROGRAMMING PANEL, precision decade programming resistors for 6 digit voltage programming and 3 digit current programming.

c) FG-100, FUNCTION GENERATOR. Precision, slow speed, triangular wave generator for voltage programming of the power supply.

d) MP 1-3000, MOTORIZED PROGRAMMER. Provides a mechanical 10-Turn potentiometer sweep.

e) VIP-1, OVERVOLTAGE/OVERCURRENT PROTECTOR, A 1% or 0.1V overvoltage will crow-bar the supply within 50 μ sec.

f) VIP-3, OVER AND UNDER VOLTAGE
OVER AND UNDER CURRENT PROTECTOR
A 1% or 0.1V over or under voltage will crow-bar the supply within 50 μ sec.

g) VIP-4, 200 Ampere Overvoltage Crow-bar. Range 5-50 volts. A 1% or 0.1V overvoltage will crow-bar supply with 50 μ sec.

h) VP-K-Series Overvoltage Protector, a 5% or 0.25V overvoltage will trigger the power supply within 5-10 μ sec. (Adjustable)

VP-KCA - for all KS Models except as listed below.

VP-KS1 - for KS 36-30(M), KS 60-20(M), KS 120-10(M).

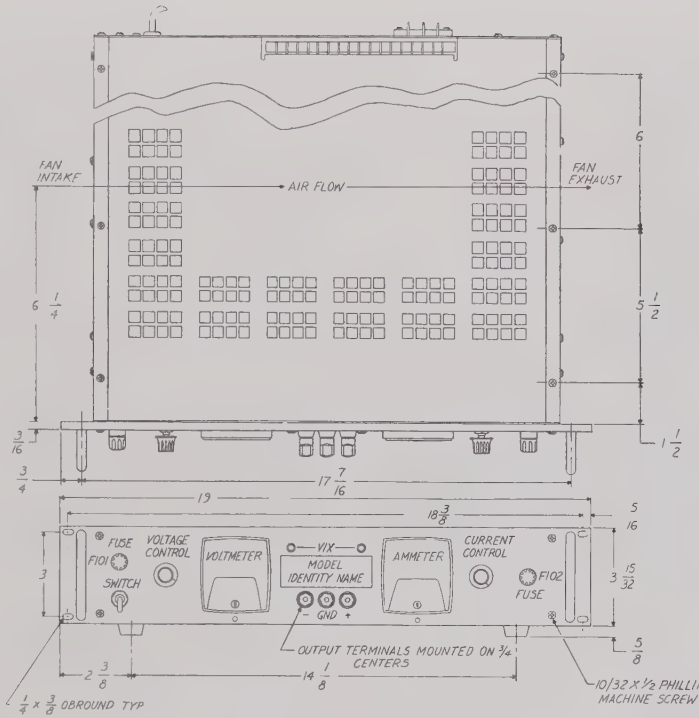
VP-KS2 - for KS 8-100(M), KS 18-50(M).

MODEL	DC OUTPUT RANGE		OUTPUT IMPEDANCE OHMS MAX.			SIZE	MAX. INPUT at 125V AC	
	VOLTS	AMPS	DC to 100 cps	100 cps to 1 kc	1 kc to 100 kc+μh		AMPS	WATTS
KS 8–15M	0–8	0–15	0.05×10^{-3}	0.01	0.04+0.4	A	4.4	320
KS 8–25M	0–8	0–25	0.03×10^{-3}	0.01	0.04+0.4	B	8.5	565
KS 8–50M	0–8	0–50	0.016×10^{-3}	0.005	0.02+0.4	C	15.5	1000
KS 8–100M	0–8	0–100	0.008×10^{-3}	0.005	0.02+0.4	D	32.0	2100
KS 18–10M	0–18	0–10	0.18×10^{-3}	0.01	0.04+0.5	A	6.7	345
KS 18–15M	0–18	0–15	0.12×10^{-3}	0.01	0.04+0.5	B	8.0	510
KS 18–25M	0–18	0–25	0.07×10^{-3}	0.005	0.04+0.5	C	14.0	900
KS 18–50M	0–18	0–50	0.035×10^{-3}	0.005	0.02+0.2	D	26.0	1800
KS 36–5M	0–36	0–5	0.7×10^{-3}	0.02	0.1 +1.0	A	4.8	290
KS 36–10M	0–36	0–10	0.4×10^{-3}	0.01	0.1 +1.0	B	8.9	580
KS 36–15M	0–36	0–15	0.25×10^{-3}	0.01	0.1 +0.6	C	12.2	860
KS 36–30M	0–36	0–30	0.1×10^{-3}	0.005	0.04+0.4	D	25.0	1600
KS 60–2M	0–60	0–2	3×10^{-3}	0.02	0.1 +1.0	A	3.0	250
KS 60–5M	0–60	0–5	1×10^{-3}	0.02	0.1 +1.0	B	7.0	500
KS 60–10M	0–60	0–10	0.6×10^{-3}	0.01	0.1 +1.0	C	13.0	1000
KS 60–20M	0–60	0–20	0.3×10^{-3}	0.01	0.1 +0.8	D	24.0	1700
KS 120–1M	0–120	0–1	10×10^{-3}	0.02	0.1 +1.0	A	3.0	250
KS 120–2.5M	0–120	0–2.5	5×10^{-3}	0.02	0.1 +1.0	B	7.0	500
KS 120–5M	0–120	0–5	3×10^{-3}	0.01	0.1 +1.0	C	13.0	1000
KS 120–10M	0–120	0–10	1×10^{-3}	0.01	0.1 +1.0	D	24.0	1700

DIMENSIONS

SIZE	H"	W"	D"
A	3 1/2	19	14 3/8
B	5 1/4	19	16
C	7	19	16
D	8 3/4	19	20

TABLE 1-1 SPECIFICATIONS, KS SERIES POWER SUPPLIES



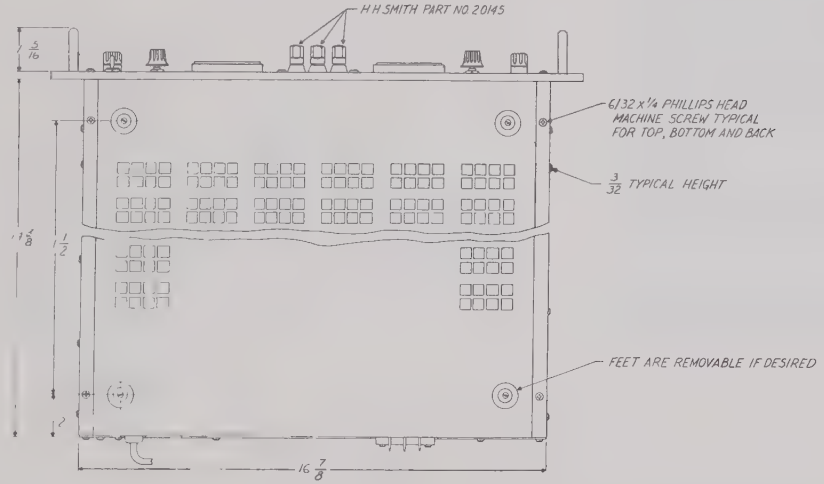
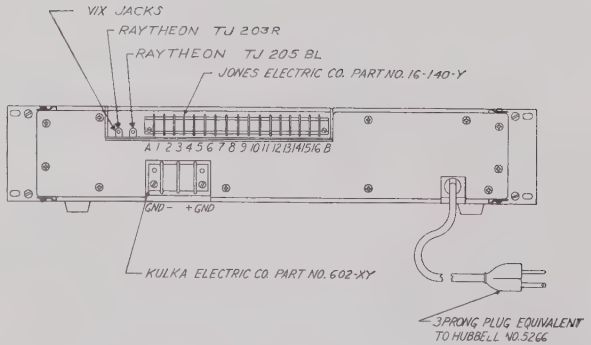
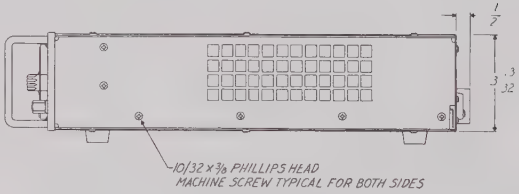

H.H.SMITH PART NO. 2014S
5/16
6/32 x 1/4 PHILLIPS HEAD MACHINE SCREW TYPICAL FOR TOP, BOTTOM AND BACK
3/32 TYPICAL HEIGHT
1 1/8
1 1/2
FEET ARE REMOVABLE IF DESIRED
16 7/8

FIG. 1-3 OUTLINE DRAWING


VIX JACKS
RAYTHEON TJ 203R
RAYTHEON TJ 205 BL
JONES ELECTRIC CO. PART NO. 16-140-Y
A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 B
GND - + GND
KULKA ELECTRIC CO. PART NO. 602-XY
3 PRONG PLUG EQUIVALENT TO HUBBELL NO. 5266



REAR OUTPUT TERMINAL FUNCTIONS

A	
1	- CURRENT SENSING
2, 3	PROGRAM OF CURRENT BY VOLTAGE
4, 5	PROGRAM OF CURRENT BY RESISTANCE
6, 7	REMOTE LOAD SENSING NEGATIVE
8	- GROUND
9, 10	REMOTE LOAD SENSING POSITIVE
11, 12	PROGRAM OF VOLTAGE BY RESISTANCE
13, 14	PROGRAM OF VOLTAGE BY VOLTAGE
15, 16	PARALLEL OPERATIONS
B	

NOTES:
1. THIS DRAWING USED FOR MODELS KS8-15M, KS18-10M, KS36-5M, KS60-2M, KS120-1M
2. MAT'L, COVER NO. 16 COLD ROLLED STEEL, CADMIUM FINISH WITH A CHRONAK WASH PANEL ALUM. ALLOY LIGHT GRAY FEDERAL SDT. 595 COLOR # 26440
3. FUSE DATA -

MODEL	FUSE SIZE F101	FUSE SIZE F102
KS18-10M	8 AMP	1AMP
KS36-5M	5AMP	1AMP
KS60-2M	5AMP	1AMP
KS8-15M	7AMP	1AMP
KS12C-1M	5AMP	1AMP

4. REFER TO KEPCO CATALOG FOR DETAILED SPECIFICATIONS

SECTION II - INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This power supply has been completely tested and inspected at the factory prior to packing and is ready for installation and operation. No special precautions are necessary for unpacking the power supply. Inspect the instrument for obvious shipping damage before attempting to operate it. Perform an operational check as described in Par. 2-14. If there is any indication of damage, file a claim immediately with the transport service responsible.

2-3 TERMINALS AND CONTROLS

2-4 For the location of all terminations and controls, refer to Fig.s 2-2 and 2-3 as well as Tables 2-1 and 2-2. The nomenclature used will be followed throughout this manual.

2-5 A.C. INPUT REQUIREMENTS

2-6 This power supply is normally supplied for operation on a single phase, nominal 115 VAC line. For conversion to 230 VAC line operation, refer to Fig. 2-1. Refer to Table 1-1 for Input Current requirements.

2-7 GROUNDING

a) AC Ground. The power supply is equipped with a 3 wire safety line cord and polarized plug. The third (green) wire in the line cord is connected to the chassis and the case of the unit. If a two terminal receptacle in combination with an adaptor is used, it is imperative that the chassis of the power supply be returned to AC ground with a separate lead.

b) DC Ground. The D.C. output is isolated from the A.C. power line and from any direct connection to chassis or ground. The positive side of the output is connected to chassis through a capacitor in series with a resistor. The maximum voltage that can be supported between either output terminal and ground or chassis is 500V DC plus the maximum output voltage of the power supply. Either side of the output may be grounded. Convenient grounding terminals are provided at the front panel binding post (on units so equipped) or at the rear terminal strip.

2-8 LOAD CONNECTION

2-9 The load may be connected to the front panel binding posts (on units so equipped) or at the rear terminals. The regulation specifications as given in Section I are valid for rear terminal connections only. If optimum regulation directly at the load is essential, remote error sensing as described in Par. 3-16 must be applied.

2-10 COOLING

2-11 The power transistors and the rectifier assembly are maintained within the correct operating temperature by fan(s) circulating air laterally through the power supply. Side-panel openings and the top of the case must be kept clear from obstructions to insure proper circulation.

2-12 If the supply must be rack mounted or installed into confined space, care must be taken that the ambient temperature does not rise above the limit specified in Section I of this manual.

2-13 A protective thermostat located in one of the pass assemblies (Refer to Fig. 4-4) is interconnected with a power relay interlock to remove the line power in the event of excessive ambient temperature or a failure in the cooling system. If a thermal cut-out occurs, re-cycling of the power switch is required after proper thermal conditions have been restored.

2-14 OPERATIONAL CHECK

2-15 A simple operational check after unpacking and before permanently installing the power supply is advisable. The purpose of the test is to check the power supply for any damage resulting from shipment.
Note: Refer to Fig. 2-2 and Fig. 2-3 for location of front and rear terminations.

a) Connect power supply to 115 VAC line. Refer to Paragraph 2-5 for 230 V line operation and to Table 1-1 for input current requirements.

b) Turn "Current Control" fully clockwise. Rotate "Voltage Control" fully counter clockwise and then clockwise for one turn. For units without metering, connect a DC voltmeter across the rear output terminals. The range of the voltmeter must be sufficient to cover the maximum output voltage of the power supply.

c) Turn power "on". Slowly rotate the "Voltage Control" clockwise and observe the gradual increase of the output voltage. The "Voltage" VIX light should be on and the "Current" VIX light should be out. Turn power "off".

d) Connect a short circuit across the output terminals, consisting of a length of heavy copper wire. For unmetered models an ammeter with sufficient range to cover the maximum output current of the power supply may be connected in series with the short circuit.

e) Turn power "on". Rotate the "Current Control" slowly clockwise. A smooth increase in output current should be observed on the output current meter. The "Current" VIX light should be on, and the "Voltage" VIX light should be out. Turn power "off". This completes the operational check of the power supply.

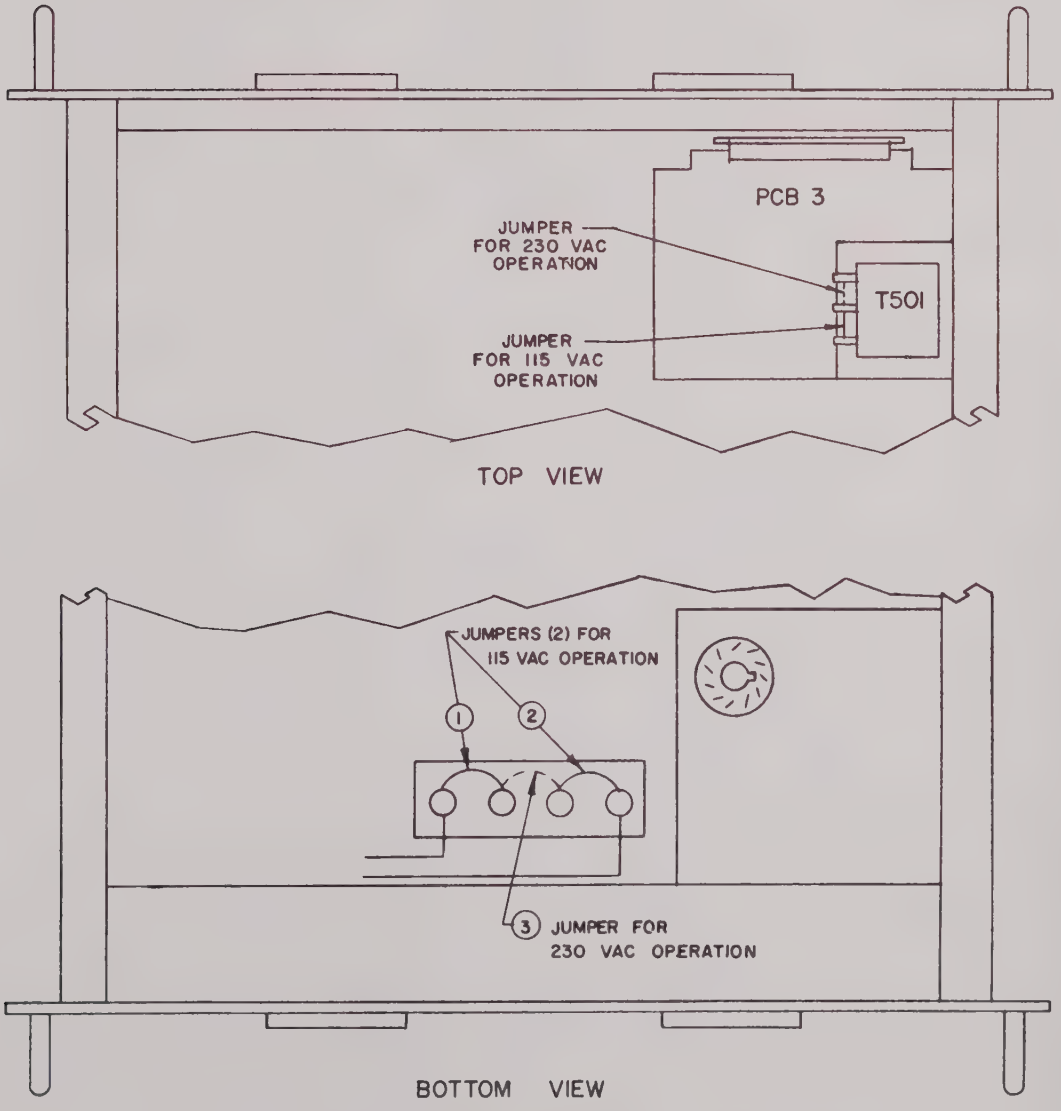


FIG. 2-1 TRANSFORMER CONNECTIONS FOR 115V AC AND 230V AC

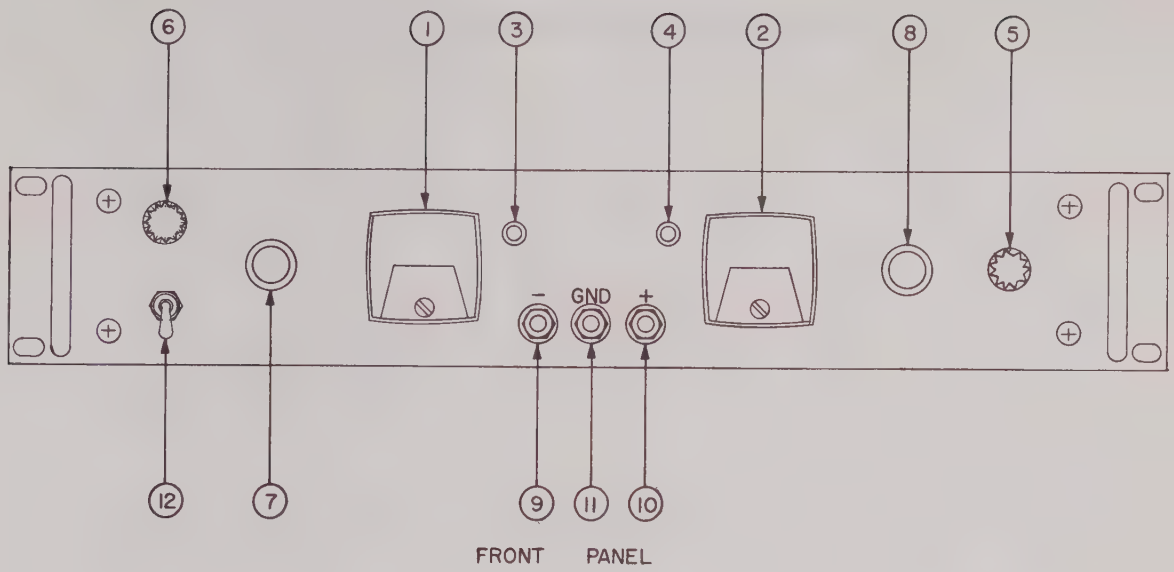


FIG. 2-2 TERMINATIONS, FRONT

TABLE 2-1 TERMINATIONS, FRONT

NO.	TERMINATION OR CONTROL	FUNCTION
1	VOLTMETER	INDICATES OUTPUT VOLTAGE
2	AMPERE METER	INDICATES OUTPUT CURRENT
3	VIX INDICATOR	DISPLAYS VOLTAGE OPERATING MODE
4	VIX INDICATOR	DISPLAYS CURRENT OPERATING MODE
5	FUSE	PROTECTS REFERENCE TRANSFORMER
6	FUSE	PROTECTS MAIN TRANSFORMER
7	VOLTAGE CONTROL	TEN TURN POTENTIOMETER, SETS OUTPUT VOLTAGE
8	CURRENT CONTROL	TEN TURN POTENTIOMETER, SETS OUTPUT CURRENT
9	OUTPUT TERMINAL(-)	MINUS TERMINAL, DC OUTPUT
10	OUTPUT TERMINAL (+)	PLUS TERMINAL, DC OUTPUT
11	OUTPUT TERMINAL (GND)	CHASSIS CONNECTION, RETURN TO AC GROUND
12	LINE SWITCH	CONNECTS UNIT TO AND FROM AC POWER LINE

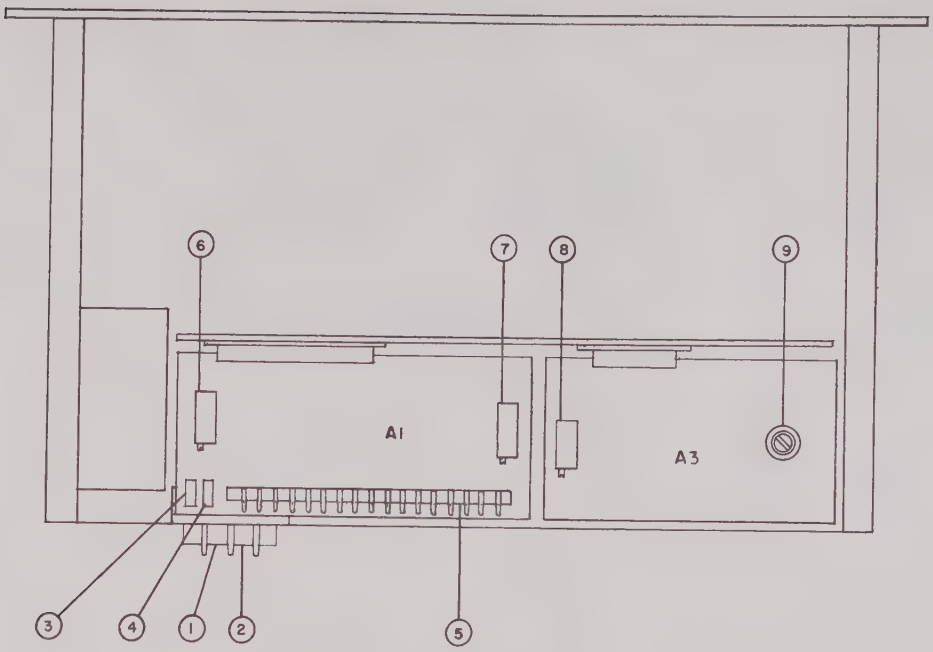


FIG. 2-3 TERMINATIONS, REAR

TABLE 2-2 TERMINATIONS, REAR

NO.	TERMINATION OR CONTROL	FUNCTION
1	OUTPUT TERMINAL(−)	MINUS TERMINAL, DC OUTPUT
2	OUTPUT TERMINAL(+)	PLUS TERMINAL, DC OUTPUT
3	VIX CONNECTOR	VIX SIGNAL OUTPUT (+ IN V MODE, − IN I MODE)
4	VIX CONNECTOR	VIX SIGNAL OUTPUT (− IN V MODE, + IN I MODE)
5	REAR BARRIER STRIP	16 CONNECTIONS TO INTERNAL CIRCUITRY (SEE SECT. 3)
6	R40, POTENTIOMETER	MAXIMUM CURRENT ADJUST (SEE SECT. 5)
7	R42 POTENTIOMETER	MAXIMUM VOLTAGE ADJUST (SEE SECT. 5)
8	R327 POTENTIOMETER	MAXIMUM PASS VOLTAGE ADJUST (SEE SECT. 5)
9	R322 POTENTIOMETER	LINE VOLTAGE FEEDBACK ADJUST (SEE SECT. 5)

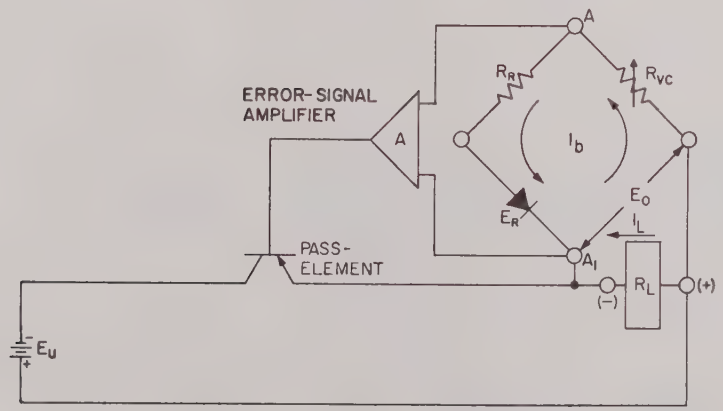
3-1 REMOTE PROGRAMMING OF KEPCO POWER SUPPLIES

3-2 General: In the Kepco Series "KS" Power Supplies, two comparison bridge circuits are used, each of which permit full range programming by resistance, voltage, current or conductance. The versatility of these circuits are so great that only the more common modes of operation can be described in this manual. For a more thorough coverage of power supply applications the "Kepco Power Supply Handbook", available from the Kepco Publication Department, is recommended.

In order to familiarize the user of this equipment with the power supply terminology used in this manual, and with the various modes of operations described in the following pages, the basic relationships governing the Kepco Bridge regulator should be clearly understood and kept in mind.

The bridge consists of four arms with the error amplifier connected to the "null" points (A, A_1). (See Fig. 3-1) The error amplifier, the power-source and the pass element constitute an inverting power amplifier which tends to regulate in such a way that equations (1), (2), and (3) are always valid. With these three basic equations in mind, the implications of the circuit variations given in the following paragraphs should become evident.

FIG. 3-1 KEPCO COMPARISON BRIDGE (SIMPLIFIED)



E_u = Unregulated Source
I_L = Load Current
I_b = Bridge Current
E_o = Output Voltage
E_r = Reference Voltage
R_L = Load Resistance
R_{vc} = Voltage Control Resistance
R_r = Reference - Resistance
A = Open Loop Gain Of Error Signal Ampl.

At balance: $E_{AA'} = 0$

(1) $\frac{E_r}{R_r} = \frac{E_o}{R_{vc}}$ (2) $I_b = \frac{E_r}{R_r}$ (3) $E_o = I_b R_{vc}$.

3-3 ADJUSTMENTS FOR EXACT PROGRAMMING RATIO

3-4 Definition. The setting of the "Voltage Control" on the front-panel adjusts the output voltage at a fixed, resistance to voltage ratio, which is determined by the bridge-current (I_b) flowing through the voltage control potentiometer (R_{VC}). Referring to our defining equations in Paragraph 3-2, and combining equations (1) and (2), we have: $E_o = I_b R_{VC}$ (equation 3). If therefore the bridge current is equal to 10 ma (as in all KS power supplies) we need, by Ohm's Law, 100 Ohms of control resistance (R_{VC}) for every volt of output: 10 ma (100 Ohms)= 1 volt. The ratio of the control resistance to the output voltage R_{VC}/E_o, which in the present case is established as 100 Ohm/volt, is termed the "Control Ratio" of the power supply.

3-5 Deviations. To compensate for inherent component tolerances, the control ratio in all KEPCO KS power supplies is adjusted slightly smaller than 100 ohm/volt. Also, a small error is introduced by the minute negative off-set voltage encountered at the output terminals when the voltage control is set to its maximum counterclockwise position. (Since $R_{VC} = 0$, in this case, we could expect, according to equation (3) that E_o would be zero). Both "inaccuracies" have been purposely designed into the power supply to facilitate precision adjustment of the programming ratio and are of no consequence in the ordinary operation of the power supply.

3-6 Adjustment. Resistance programming with precision decades or other highly accurate resistances require a control ratio accuracy comparable to the tolerances of the precision programming components. Two adjustments towards this end are necessary in the KEPCO KS Power Supply and described below.

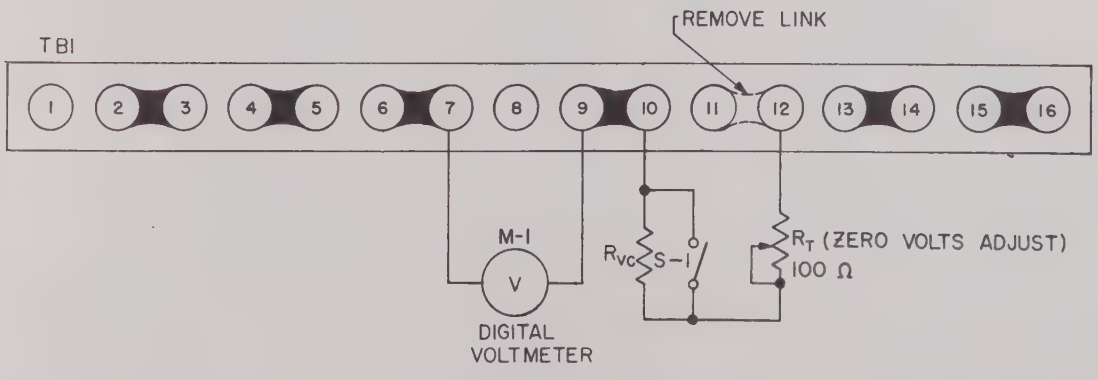


FIG. 3-2 CONNECTIONS FOR PRECISION PROGRAMMING RATIO ADJUSTMENT

3-7 PROCEDURE

a) Equipment Required:

1) Precision digital or differential voltmeter.

2) Precision resistor, 0.1% or better. (The value is not critical, but must be known precisely. For every 100 ohms, 1 volt output will appear across the voltmeter. This resistor will be externally connected as R_{VC}).

3) Adjustable, wire-wound resistor, 100 ohms. (A 15-turn wire-wound "TRIMPOT" potentiometer or its equivalent is recommended. This trimmer will be used as a zero adjustment).

4) Single Pole, single throw switch.

b) With line power removed from the power supply, remove links on the rear barrier strip between terminals (9) and (10) and between terminals (11) and (12).

c) Connect external components as shown in Fig. 3-2.

d) Turn line power "on". With S-1 open, and R_{VC} say 500 ohms, (known) approximately 5 volts output voltage will be read out on the digital voltmeter.

e) Adjust R42 Calibrate Control, for precisely 5.00 volts, (On printed circuit amplifier board, Fig. 2-3). Close S-1. Adjust R_t for precise Zero on the voltmeter.

f) Repeat (e) until no further readjustment on R42 or R_t is necessary.

CAUTION: Heavy duty output terminals for load connections are provided on the rear of the power supply. Do not connect the load to TB1, the barrier-strip on the printed circuit board. The terminals on this barrier-strip are for connections of control components and monitoring devices only and can not carry heavy current.

3-8 PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL RESISTANCE

3-9 General. The output voltage may be programmed or controlled over its entire range at the nominal 100 ohm/volt programming ratio of the KS power supplies. (If a precise ratio is desired, refer to Paragraph 3-3). In this mode of operation, the internal voltage control (R_{VC}) is disconnected and an external or remote voltage control resistance

is substituted. This resistance may take the form of a precision decade, fixed and step-switch controlled resistors or another potentiometer.

3-10 The relationships governing this type of programming are given by

$E_o = R_{vc} \frac{E_r}{R_r}$ (eq. 1) and since $\frac{E_r}{R_r} = I_b$ (eq. 2), we can combine Eq. (2) and Eq. (1), to get $E_o = I_b R_{vc}$ (Eq. 3). Since I_b is (a nominal) 10 ma, 100 ohms control resistance must be provided for each volt of output. This corresponds to a programming ratio of 100 ohm/volt.

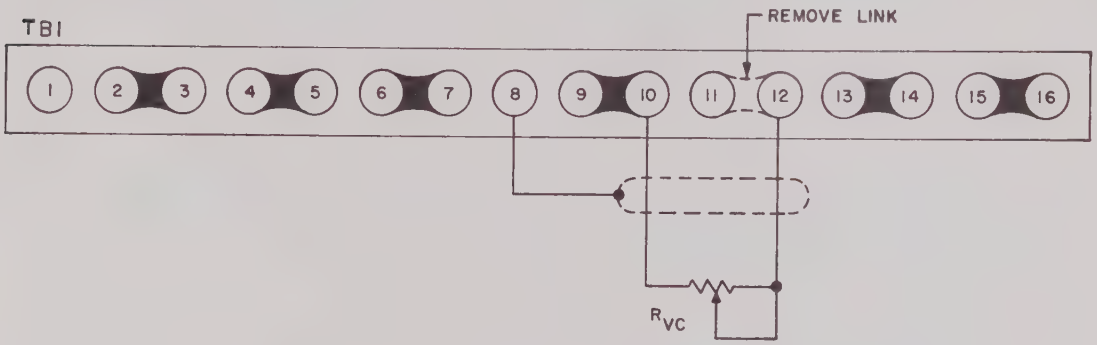


FIG. 3-3 CONNECTIONS FOR RESISTANCE PROGRAMMING

3-11 PROCEDURE

a) Remove link between terminals (11) and (12) at the rear barrier strip.

b) Using a shielded, twisted pair of wires, connect the external control resistance to terminals (10) and (12). Connect the shield to terminal (8).

NOTE: a) All resistors, used for external programming, must be high quality, wire wound units with a temperature coefficient of at least 20 ppm. Step-switch devices must be of the "make before break" variety.

b) The quiescent d.c. current through the programming resistors is the bridge current, or 10 ma. However, when programming large voltage excursions an error current flows. The power stored in the output capacitors will try to discharge partially through the control resistance and large peak currents may result. Therefore, the power dissipation rating of the control resistance should be several times that of the actual power dissipated under quiescent d.c. conditions.

3-12 PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL VOLTAGE

3-13 The output voltage of the KEPCO KS Power Supply can be controlled by an external, variable voltage source which replaces the fixed, built-in reference source. This mode of operation is referred to as "Voltage Programming". It can be mathematically expressed by referring to basic equation (1):

$\frac{E_r}{R_r} = \frac{E_o}{R_{vc}}$. Solving for E_o, $E_o = E_r \frac{R_{vc}}{R_r}$.

Denoting the variable programming source E_i and substituting for E_r we have:

$$E_o = -E_i \frac{R_{vc}}{R_r} \quad \text{(equation 4)}$$

Consequently, if E_i is varied in this expression and the ratio $\frac{R_{vc}}{R_r}$, which represents the closed loop gain of the system, is held constant, the output voltage E_o will vary linearily with E_i. Referring back to equation (4) we see that the expression is similar to the inverted amplifier equation for an operational amplifier. The voltage programmed power supply does in fact become a unipolar power amplifier with potentially very high power gain but with limited frequency response. (Refer to Fig. 3-4). The limited frequency response is largely due to the effect of the output capacitor C_o acting as a low-pass filter and preventing the output voltage (E_o) from varying rapidly. The range in which E_o can be varied is limited only by the maximum output voltage of the power supply and by the leakage current of the comparison amplifier. This leakage current is in the order of 10μA flowing opposite to I_b, the programming current. It is therefore desirable to select I_b sufficiently high, in order to keep the leakage current insignificant with respect to I_b. For critical applications, the leakage current can be compensated out. The "Kepco Power Supply Handbook" provides information towards this end.

3-14 A practical example to illustrate the method of voltage programming will be given below:

EXAMPLE: A Kepco KS 36-10 power supply is to be programmed over its full range from a variable, unipolar source, with a peak output voltage of 3 volts and capable of delivering 10 ma of stable current. The internal voltage control and therefore the programming ratio of 100 ohm/v are to be retained. The programming ratio of 100 ohm/volt pertains to the programming source as well. Consequently the coupling resistor (R_i) must be 300 ohms.

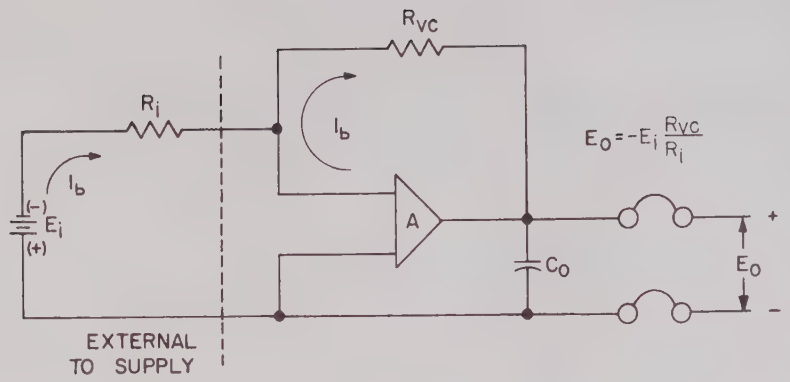


FIG. 3-4 VOLTAGE PROGRAMMING, OPERATIONAL NOTATION

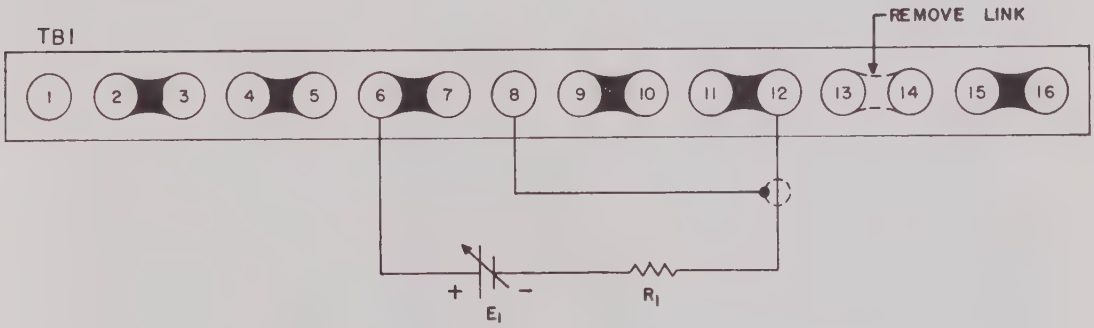


FIG. 3-5 CONNECTIONS FOR VOLTAGE PROGRAMMING

3-15 PROCEDURE (Refer to Fig. 3-5)

a) Remove link between terminals (13) and (14) on the rear barrier strip.

b) Connect selected components as shown, observe polarities.

c) Set the amplitude or voltage control of the programming source to the maximum selected programming voltage (3V).

d) Turn on the power supply to be programmed and the external programming source. Adjust the "Voltage Control" of the power supply to the selected maximum output voltage (36V).

e) The output voltage will now track variations in the programming voltage at the proportion established, (1:12).

3-16 REMOTE ERROR SENSING

3-17 GENERAL. The error sensing terminals (6) and (10), at the rear barrier strip are the input terminals to the regulating system of the power supply and are normally connected to the output terminals, providing specified regulation at these points. Voltage drops due to load current in the load connecting wires would degrade regulation directly at the load. Remote Error Sensing can be used to compensate for voltage drops up to 0.5 volts in each load wire, and provide specified regulation directly at the load.

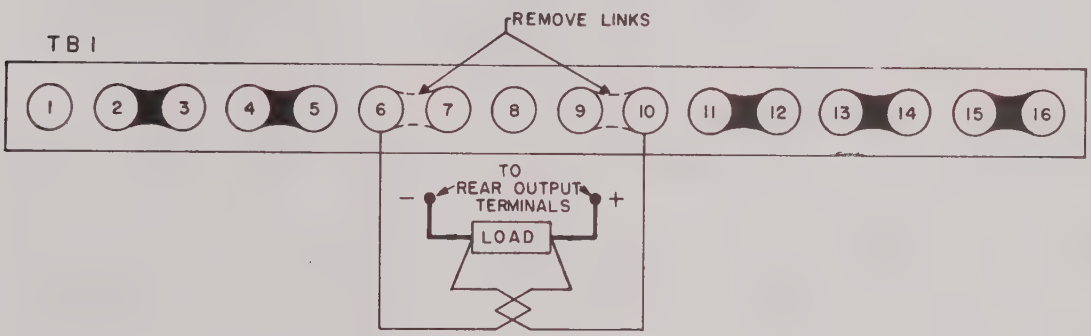


FIG. 3-6 CONNECTIONS FOR REMOTE ERROR SENSING

3-18 PROCEDURE (Refer to Fig. 3-6)

a) Remove links between terminals (6)-(7) and (9)-(10) on the rear barrier-strip. These links remove the error sensing from the output terminals and must be replaced when Remote Error Sensing is not being used.

b) Connect a twisted wire pair to the error sensing terminals (6) and (10). Observe polarity. Terminal (10), the positive error sensing terminal, must go to the positive side of the load, while terminal (6), the negative error sensing terminal must be connected to the negative side of the load. The error sensing wires carry the error signal and the bridge current but not the load current and may therefore be constructed from relatively small diameter wires, such as No. 20 AWG.

CAUTION: 1) OPEN LOAD LEAD. Before the power supply is turned on, make absolutely certain that the load wires are connected securely. If a loadwire should beccme disconnected while error sensing is used, the regulator will attempt to main-

tain load current flow through the sensing wires and damage to the power supply circuitry will result.

2) OPEN SENSING LEAD. Do not allow the power supply to operate with an open circuit between sensing terminals and their respective load terminals. This would degrade the regulation severely, cause the output voltage to rise, and increase the output ripple sharply. The output voltage rise in such a case is limited automatically to approimately 1.5 volts to protect the load.

3) Twisted loadwires of ample diameter are helpful in reducing transient recovery time. Stability problems when working into other than resistive loads can often be resolved by connecting a capacitor directly across the remote load.

3-19 PROGRAMMING OUTPUT CURRENT WITH EXTERNAL RESISTANCE

3-20 The output current of the KS power supply may be controlled externally by disconnecting the internal "Current Control" potentiometer and substituting an external control resistor. This external control may be fixed, stepped, or continuously variable, and it may be remotely located. If fixed resistors are used to step-control the current output, the switches used must be of the "Make Before Break" variety. (Shorting Contacts)

NOTE: The internal (or external) current control may in some units not produce output current for the first turn, due to a negative offset at the current amplifier. If start of control from zero is considered important, proceed as follows:

1) For local operation (Front Panel Control):
   A small, variable resistor may be inserted between rear barrier strip terminals (4) - (5) and adjusted with the current control fully counter-clockwise until output current just starts.
2) For remote current control: See Fig. 3-7

3-21 KEPCO KS power supplies generally use 0.5 volt sensing voltage and a 50 ohm "Current Control" potentiometer, resulting in a current programming ratio of 100 ohm/volt. The only exceptions in the KS series are Models KS 60-2, KS 120-1, and KS120-2.5, which use 1 volt of sensing and a 100 ohm control, retaining however the 100 ohm/volt programming ratio. Any external combination of resistors or any continuous control resistance, equal to 50 ohm (or 100 ohm in case of the KS 60-2, KS 120-1, or KS 120-2.5) will program the output current of the KS supply through its entire range. An example of a step control programming set-up is given in the procedure below.

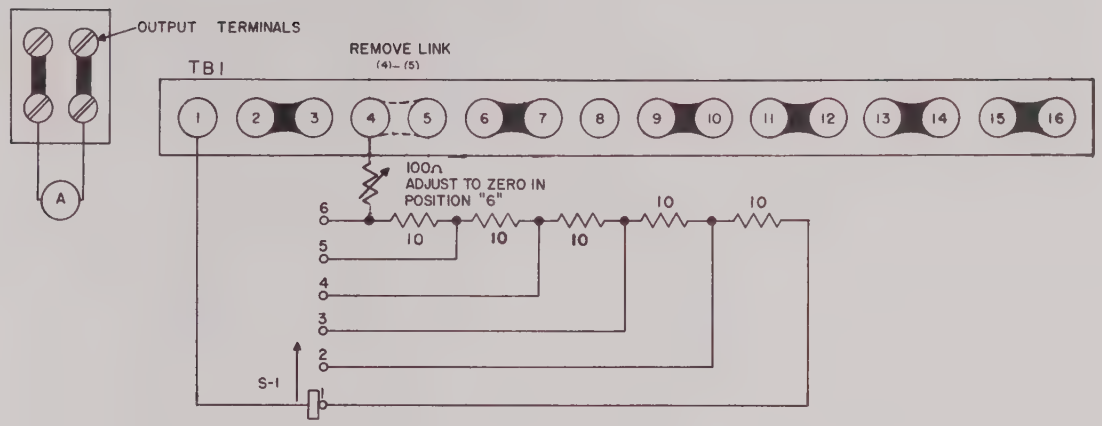


FIG. 3-7 CONNECTIONS FOR RESISTANCE PROGRAMMING (CURRENT MODE)

3-22 PROCEDURE

3-23 EXAMPLE: The output current of a KS 18-10 is to be programmed in steps of 2 Ampere up to the maximum output current of the unit.

a) Since we need 50 ohms total resistance for R_{cc}, five 10 ohm resistors are connected to a 6 position switch (with shorting contacts) as shown in Fig. 3-7.

b) Connect an ampere-meter as a short circuit across the output terminals of the power supply.

1) The range of the ampere meter must be sufficient to include the maximum output current of the unit.

2) The desired accuracy of the output current steps, will depend upon the accuracy of the meter and careful calibration.

3) The connecting leads to the meter should be short and sufficient in diameter to carry the maximum current.

c) Turn power supply "on". With S-1 in position as shown, adjust R40 (Refer to Fig. 2-3 for location) to the exact maximum output current (10A). Tranfer SW-1 to position 6 and adjust for exact zero output current.

d) All successive positions will yield the proportional output current,

pos 1) = 10 A
pos 2) = 8 A
pos 3) = 6 A
pos 4) = 4 A
pos 5) = 2 A
pos 6) = 0 A

3-24 PROGRAMMING OUTPUT CURRENT WITH EXTERNAL VOLTAGE

3-25 The output current of the KS power supply can be voltage programmed in a manner similar to that described in Paragraph 3-12. The fixed reference supply (E_r and R_r) in the current bridge circuit is removed and replaced by a variable programming source E_i with coupling resistor R_{rc}. The output current will vary in accordance with the equation $I_o = \frac{E_i R_{cc}}{R_{rc} R_s}$, where R_s is the current sensing resistor and R_{cc} the Current Control. If the original programming ratio is to be maintained, the programming source must be capable of supplying 10 ma of stable current. The value of R_{rc}, the external coupling resistor is found by multiplying the maximum programming voltage (E_i) by the control ratio: $R_{rc} = E_i$ (100 Ohm/volt of sensing). R_{rc} should be variable to be able to adjust the output current to its maximum rated value. An example will be shown below to illustrate the application of this mode of operation.

3-26 EXAMPLE: A KS 8-15 is to be voltage programmed in the current mode from zero to full output current. The programming source is a unipolar, variable supply, capable of delivering at least 10 ma and with a maximum voltage of 25 volts.

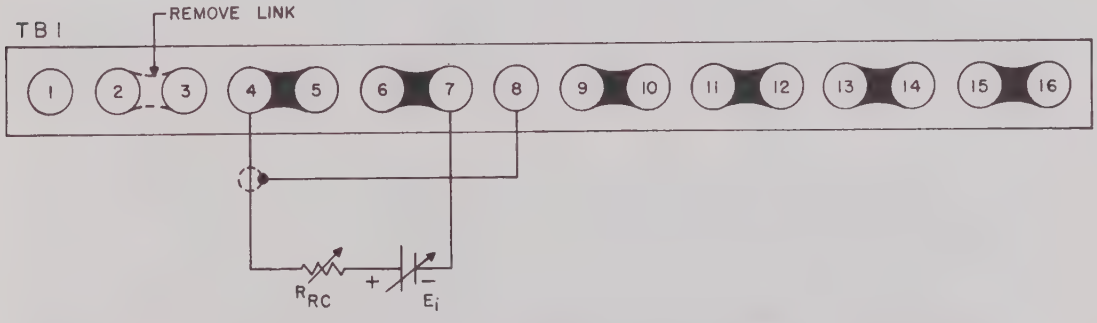


FIG. 3-8 CONNECTIONS FOR PROGRAMMING OUTPUT CURRENT WITH EXTERNAL VOLTAGE

3-27 PROCEDURE:

a) Select the external coupling resistor R_{rc}. Since the external programming source is capable of delivering 10 ma, the 100 ohm/v control ratio can be maintained. R_{rc} is found by multiplying the maximum amplitude of the programming source (E_i max.) by this ratio:

$$E_i \text{ max.} \left(\begin{matrix}\text{Programming} \\ \text{Ratio}\end{matrix}\right) = 25 \left(\frac{100 \text{ ohm}}{V_s}\right) = 2500 \text{ ohm}$$

We will split this resistor into a fixed 2000 ohm part and an adjustable 1 K ohm potentiometer.

b) Connect the programming set-up as shown in Fig. 3-8. Turn both, "Voltage Control" and "Current Control" on the front panel of the power supply fully clockwise.

c) Connect a short circuit, consisting of an accurate Ampere meter with short connecting lead of adequate diameter, able to carry the maximum output current of the power supply, across the output terminals.

d) Set the programming source to its maximum output voltage and R_{rc} to its maximum Resistance Value.

e) Turn power supply and programming source "on". With R_{rc} at its maximum resistance value, the output current as read on the external ammeter should be below its maximum rated value. Adjust R_{rc} in the direction of decreasing resistance until output current will reach its rated maximum value. The programming source will now vary the output proportionally.

3-28 OUTPUT CURRENT REGULATION USING EXTERNAL SENSING

3-29 External sensing for the purpose of superior regulation at low currents may be used with KS power supplies. In the internal "Current Regulation" Mode, an internal sensing resistor R_s is used to generate a voltage drop proportional to the load current flowing through it. This voltage drop as applied to the current comparison bridge, constitutes the output voltage for comparison purposes. The voltage drop across R_s changes with load-current, since I_L is made variable in the KS supplies. Optimum regulation however can only be achieved over a comparatively narrow range of V_s, the voltage across sensing resistor R_s, so that in a variable current supply a compromise in the selection of R_s must be made. If external sensing is used, R_s can be selected close to its optimum value and excellent regulation of small load current over a narrow range can be achieved.

3-30 In the external sensing mode, the voltage comparison bridge is being used to regulate current. The current bridge is inactive and consequently automatic cross-over does not take place and only the "Voltage" VIX indicator will be energized. The practical application of this mode of operation will best be shown by an example.

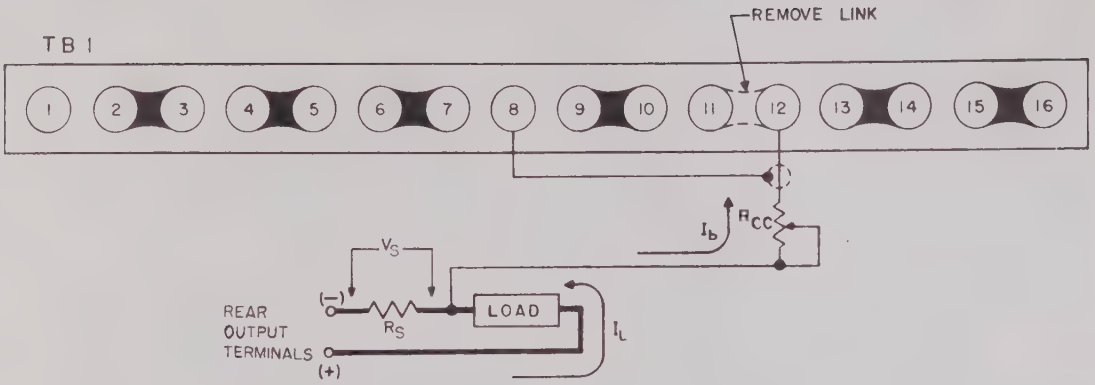


FIG. 3-9 CONNECTIONS FOR CURRENT REGULATION USING EXTERNAL SENSING

3-31 EXAMPLE:

a) A constant current of 110 ma is needed. The power supply available is a Kepco KS 8-100. Since the current required is out of this supplies' regulation range (0.5% - 100%), external sensing will be used.

b) A 1 volt sample voltage across R_S will be selected, requiring a coupling resistor R_C of 100 ohms, according to the established control ratio of the KS supply (100 ohm/volt).

c) R_S, the sensing resistor is calculated by Ohm's Law:

$$R_S = \frac{V_S}{I_O - I_b}, \quad R_S = \frac{1 \text{ volt}}{(0.11A - 0.01A)} = 10 \text{ ohm.}$$

The power dissipated in R_S, is $P_{diss} = 0.1$ watt. A 10 ohm, W.W., 1 W resistor with a T.C. of 20 ppm or better will be used.

d) Connect the selected components as shown in Fig. 3-9. If R_{CC} is made variable, the output current can be varied with it over an approximately 1:10 range. At 10 ma I_O however, the supply will lose control, because the control current which is in the order of 10 ma, will tend to cancel the load current through the sensing resistor, producing a large error signal at the comparison bridge.

CAUTION: When using external sensing, the load must be connected at all times, Since the power supply is operating with the voltage comparison bridge, opening the load wires would appear to the error amplifier as an infinite resistance load, and the maximum unregulated voltage will appear at the output.

3-32 SERIES OPERATION OF KS POWER SUPPLIES

3-33 KEPCO KS power supplies can be series connected for increased voltage output, provided the specified limits on voltage to chassis are not exceeded. When series connected, the supplies should be protected by means of a semi-conductor diode across the output terminals of each supply. The peak-inverse voltage of these diodes must be at least as large as the output voltage of the supply to which they are connected. The continuous current rating of the protective diodes must be greater than the maximum output current of the inter-connected supplies.

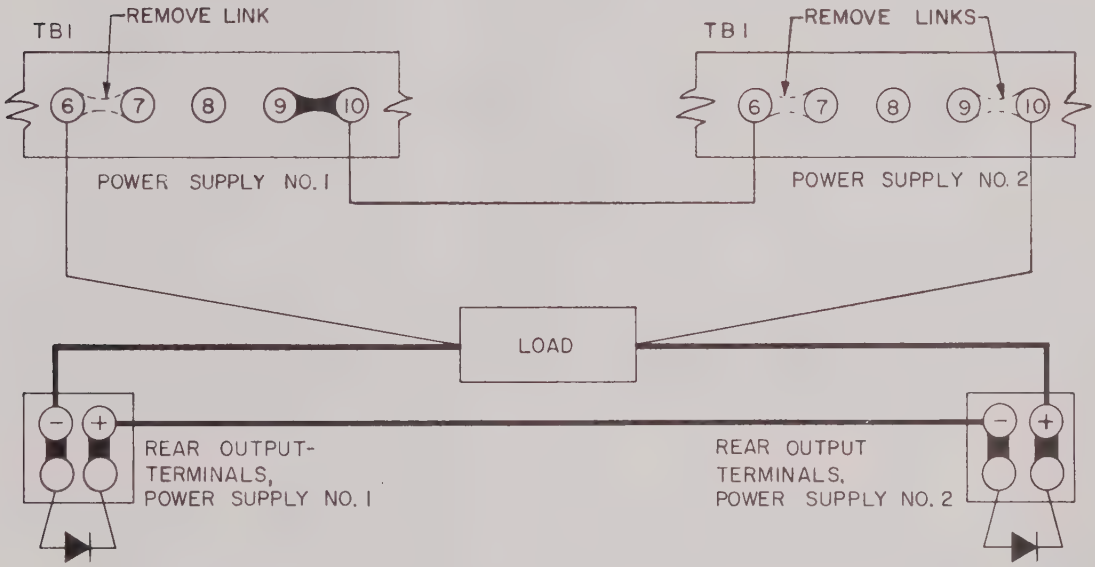


FIG. 3-10 CONNECTION FOR IN-SERIES OPERATION

3-34 PROCEDURE

a) Connect load to power supplies as shown in Fig. 3-10. Keep voltage drops in the load wires as low as possible by selecting the gauge as heavy as practicable.

b) Connect protective diodes across their respective output terminals.

c) Remove jumper-links as shown and connect error sensing leads. These leads carry negligible current and may be light gauge wire.

d) Turn both supplies on, and adjust voltage on either control as required.

3-35 PARALLEL OPERATION OF KS POWER SUPPLIES

For the purpose of obtaining higher load current, paralleling of KEPCO KS Power Supplies is possible. Several methods can be used, two of the most common ones are given below.

3-36 MASTER-SLAVE CONNECTION. In this method of paralleling, the pass-elements of both units are effectively combined and driven from a common control derived from the master supply amplifier. Up to three supplies can be operated in this manner, beyond this number, other methods must be used. (Refer to Paragraph 3-38)

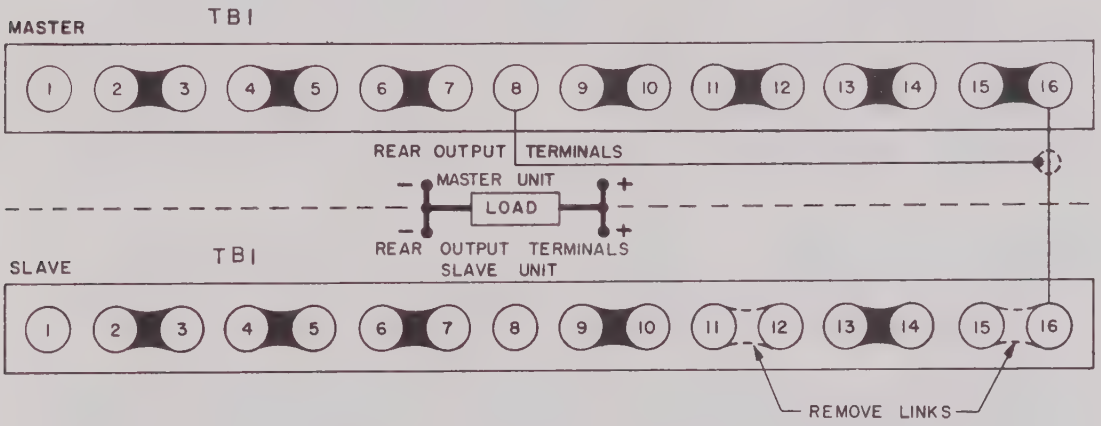


FIG. 3-11 SERIES OPERATION, MASTER-SLAVE CONNECTION

3-37 PROCEDURE (Refer to Fig. 3-11)

a) Remove jumper links between terminals (11)-(12) and (15)-(16) on the rear barrier strip of the slave unit. Join terminals (16) of both units with a shielded wire and connect the shield to terminal (8) on the master unit.

b) Connect load with equal length of wire from each power supply to insure optimum current sharing. (This becomes especially important when load currents close to the combined maximum current limits are required).

c) Connect remote error sensing, if required, from the error sensing terminals of the master unit to the load as described in Paragraph 3-16.

d) Connect power supplies to line simultaneously by means of a common power switch.

3-38 AUTOMATIC CROSS-OVER CONNECTION. This method does not involve any special interconnections, except for common A.C. powerline switching and connection of the load with an equal length of wire. Each supply is set to the desired output voltage with it's respective "Current Control" set to its maximum clockwise position. After turn-on, one of the supplies will be at a slightly higher output voltage than the rest, (Supply #1). It is this supply that will deliver all the current up to its own current limit. As the load is increased, the supply with the second highest output voltage will take over and deliver the additional current up to its "Current Control" setting, and so on, until all parallel supplies are sharing the load current. The "Current Controls" of all supplies can now be set to achieve approximately equal current sharing.

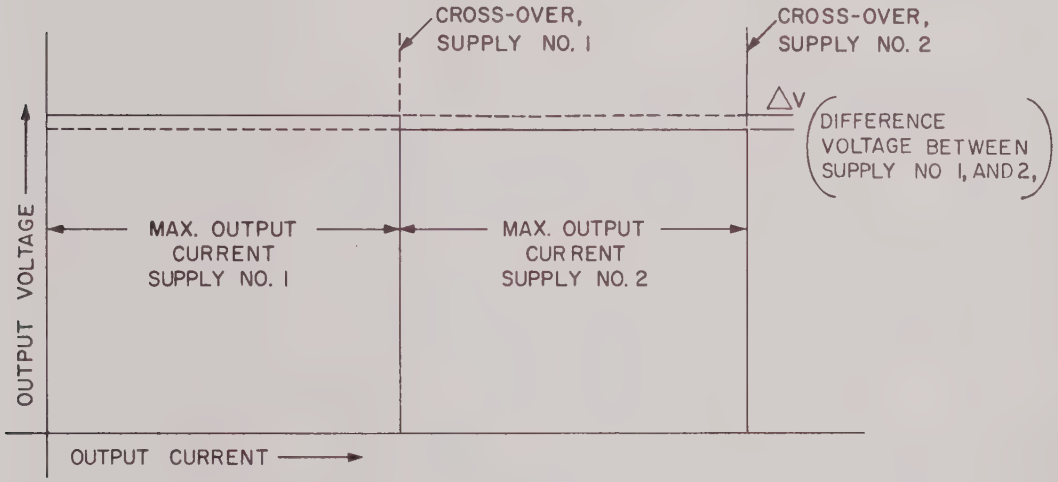

CROSS-OVER, SUPPLY NO. 1
CROSS-OVER, SUPPLY NO. 2
△V
DIFFERENCE VOLTAGE BETWEEN SUPPLY NO 1, AND 2,
MAX. OUTPUT CURRENT SUPPLY NO. 1
MAX. OUTPUT CURRENT SUPPLY NO. 2
OUTPUT VOLTAGE
OUTPUT CURRENT

FIG. 3-12 AUTOMATIC CROSS-OVER, KS POWER SUPPLIES

Fig. 3-12 shows in diagram form how power supplies operate in AUTOMATIC CROSSOVER mode. It will be obvious from the diagram that since the output voltages are never exactly equal, a "delta V" exists, which would, if an attempt were made to measure load regulation over the whole range, add to the "regulation delta V" and would result in erroneous readings. Load regulation therefore can be measured in the individual output current bands only.

NOTE: When paralleling KS power supplies, care should be exercised to avoid turning only one of the voltage controls close to zero. This precaution will prevent excessive currents in the control potentiometer as its limiting resistance is lowered.

SECTION IV - THEORY OF OPERATION

4-1 GENERAL (Refer to Fig. 4-1 and Fig. 4-2)

4-2 This section describes the major circuitry of the KEPCO KS Power Supply. The purpose of the analysis is to provide the user with a functional understanding of the unit forming thus a basis for successful operation and maintenance.

4-3 While the connecting diagram (Fig. 4-1, Table 4-1) shows the mechanical interconnection of the individual plug-in assemblies of the supply, the block diagram (Fig. 4-2) shows the functional electrical connections.

4-4 CIRCUIT DESCRIPTION

4-5 AC Input Circuit. (Refer to Fig. 4-3) AC power is introduced to the unit through a heavy duty three-wire safety cord with three-prong plug. When AC line switch S101 is closed, C501 which was completely discharged, will charge and its instantaneous peak charging current will close K501 and thereby energize the primary of T201. The relay holding current flows now from the cathode side of CR501 over thermo-switch S-701*, over relay contacts (1) and (3), through R502 and finally through the coil of K501. C501 will not completely discharge since the charging potential is still connected. Consequently, when thermo-switch S-701* is opened by over-temperature, the current path through the coil of K501 is interrupted. It's energized state can only be re-established if S101 is opened for a few seconds, thus removing the charging potential from C501 and allowing it to discharge. If S101 is now closed again and the cause for the over-temperature is corrected, allowing S-701* to assume its normally closed position again, recycling of the above described sequence takes place. The primary circuit is further protected from overloads by main-fuse F101 and reference fuse F102.

4-6 Main dc power supply. The main dc power is derived from the secondary winding on T201 with its associated bridge rectifier circuit working into a capacitor input filter. Two of the rectifiers are of the controlled type (SCR's). The main dc power supply delivers the output current and the operating voltages for the pass-elements.

4-7 Pass-Element Circuitry. (Refer to Fig. 4-4)
The pass-elements are connected in series with the negative output lead, so that the unregulated voltage from the rectifier circuit is divided between these power transistors and the dc output of the power supply. By properly "driving" the pass transistors, their equivalent resistance changes and therefore the voltage drop across them is made to change in such a way as to maintain the dc output voltage constant. The base-

* S601 on KS8-15
S901 on KS60-2, KS60-5

drive necessary for this action is supplied by a driver (A6) which itself is driven by a predriver (Q6) which gets its base drive from the output of either voltage or current comparison amplifier.

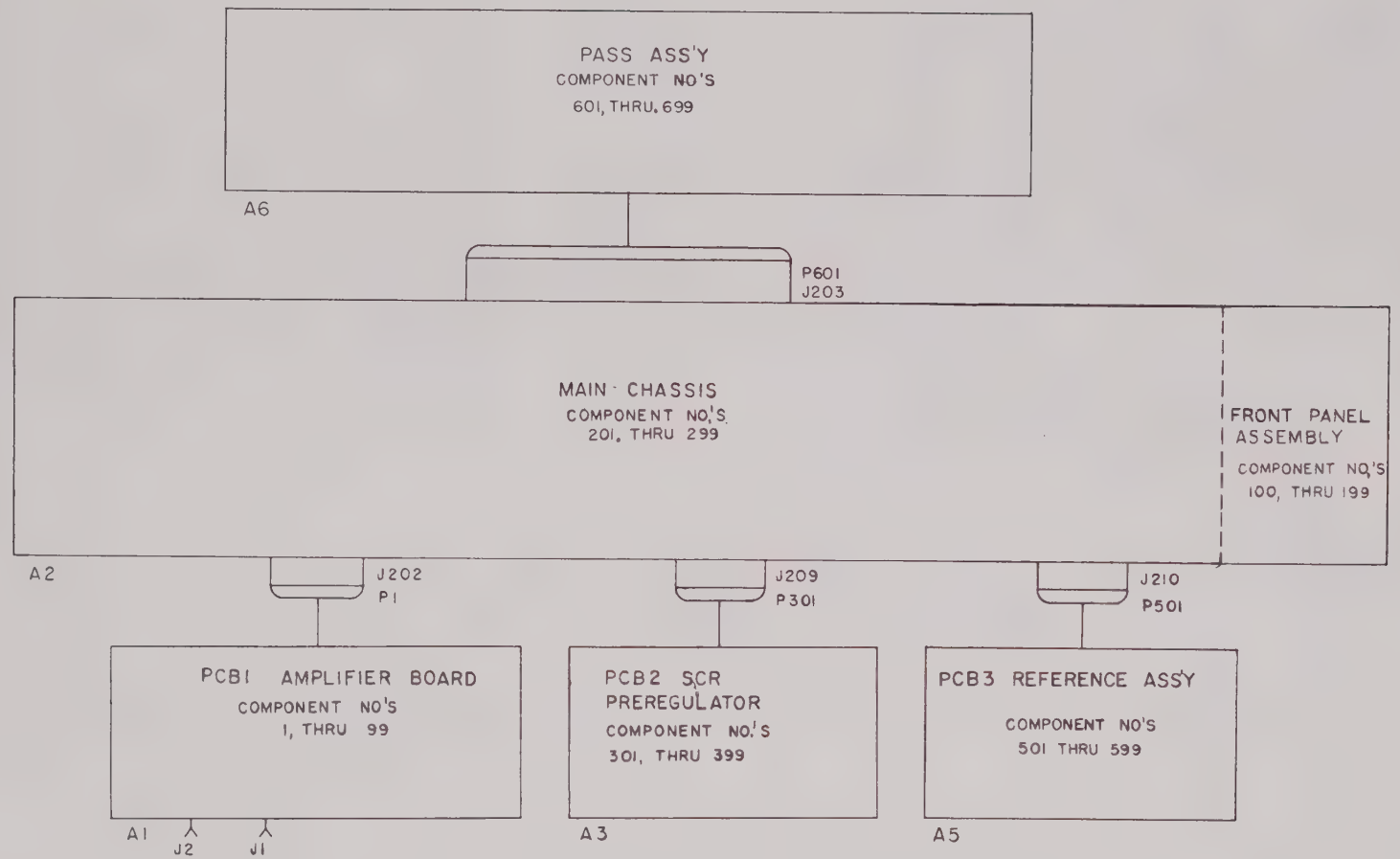


FIG. 4-1 KS 120-1 CONNECTING DIAGRAM

TABLE 4-1 SUBASSEMBLIES, KS 120-1

COMPONENT SERIES	ASS'Y NO.	PRINTED CIRCUIT BOARD NO.	ASSEMBLY DESCRIPTION
1-99	A1	PCB-1	Plug-in Assembly, Containing: Comparison Bridge, Voltage. Comparison Bridge, Current. Error Voltage Amplifier, Voltage. Error Voltage Amplifier, Current. Automatic Cross-over Stage, (OR-Gate) with cross-over signal jacks.
100	A2		Front Panel Assembly contains control components and meters (if unit so equipped).
200	A2		Main Chassis Assembly, containing: Main transformer with power rectifier & assembly pass-elements.
300	A3	PCB-2	Preregulator circuit.
400	A4		Not Used.
500	A5	PCB-3	Plug-in assembly, consisting of: Printed circuit board with reference transformer and auxiliary supplies for preregulator amplifier and pre-driver collector supply.
600	A6		Plug-in Assembly with 4 driver transistors, an over-temperature thermostat and 4 pass transistors, as well as auxiliary components.

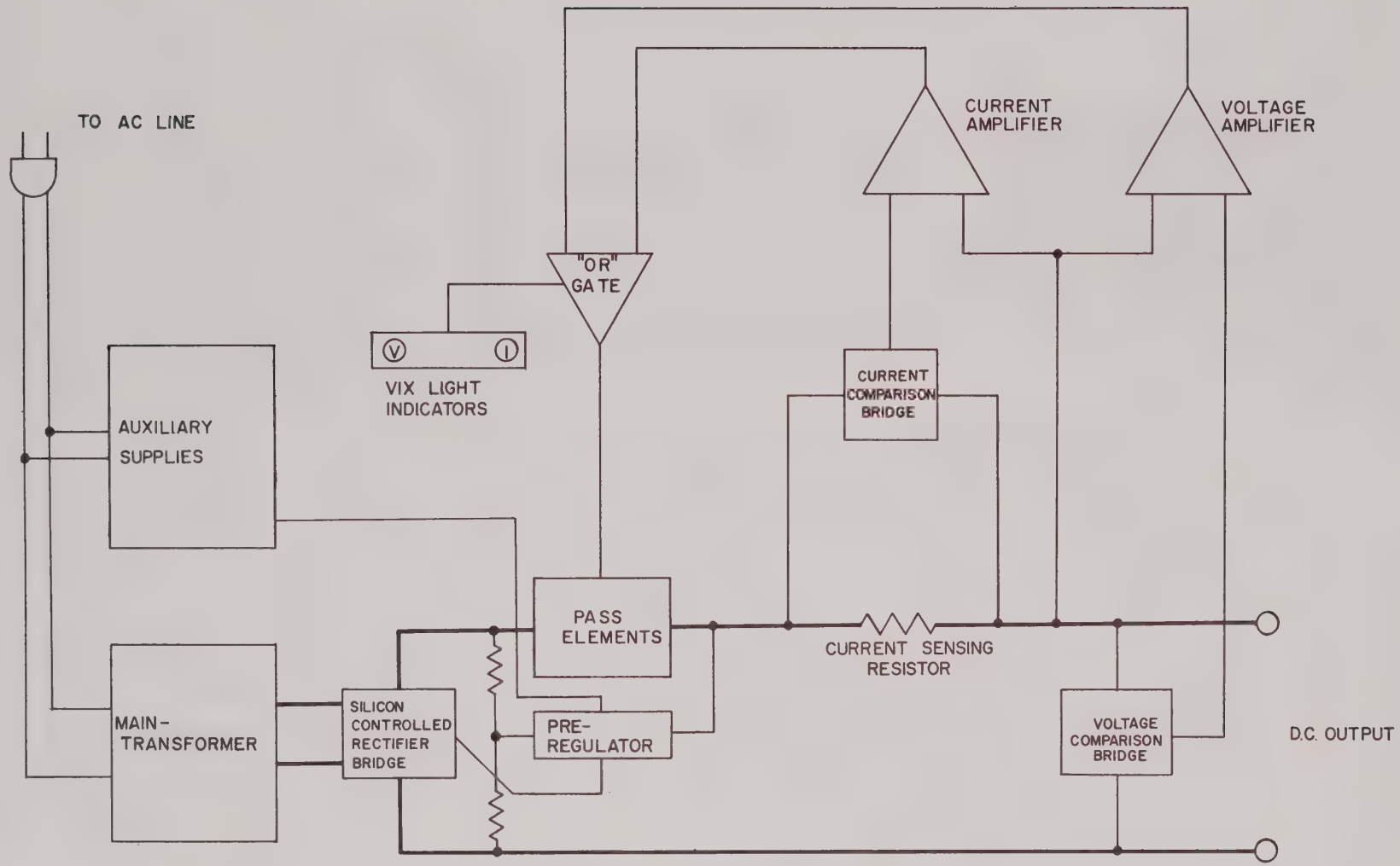
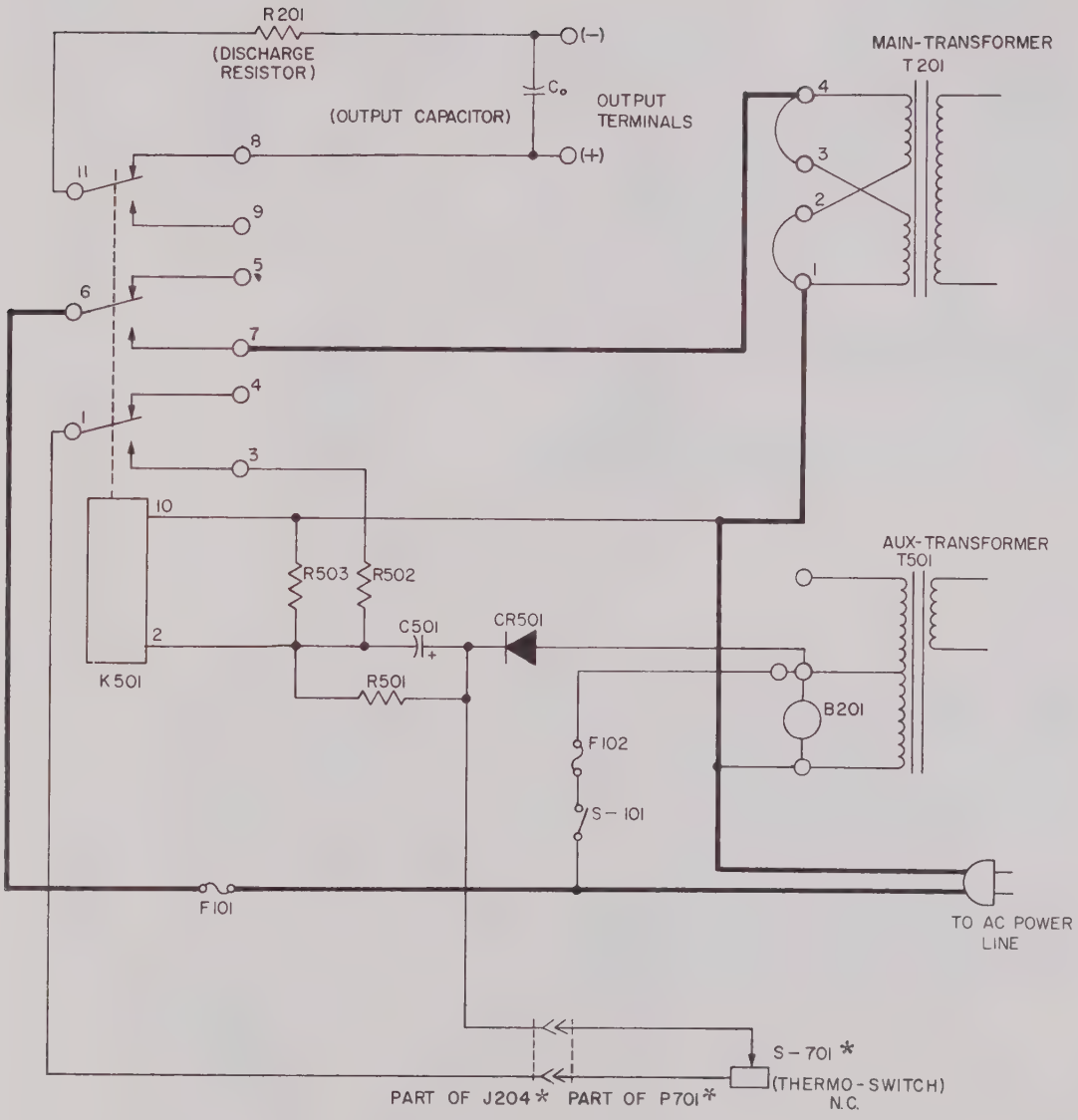


FIG. 4-2 KEPCO KS SERIES POWER SUPPLY, BLOCK DIAGRAM



Note: Reference Disignation marked (*)
may change with different models.
Refer to FIG. 4-4 for correct identification.

FIG. 4-3 AC INPUT CIRCUIT

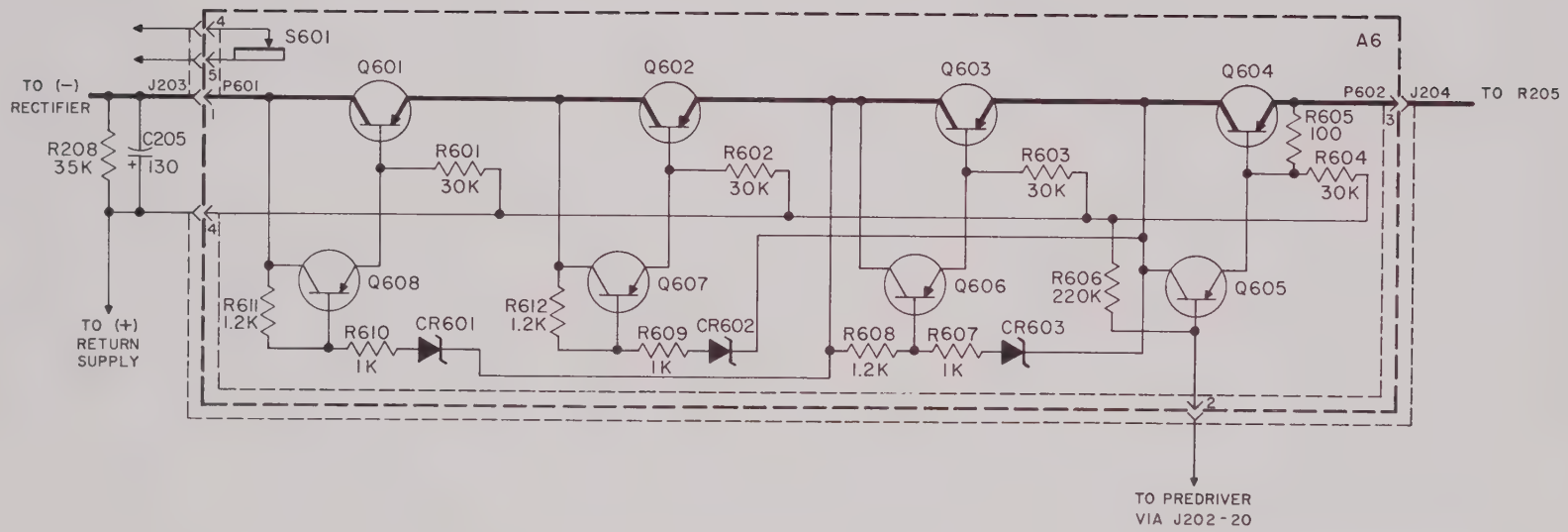


FIG. 4-4, PASS ASSEMBLY DETAIL, KS 120-1

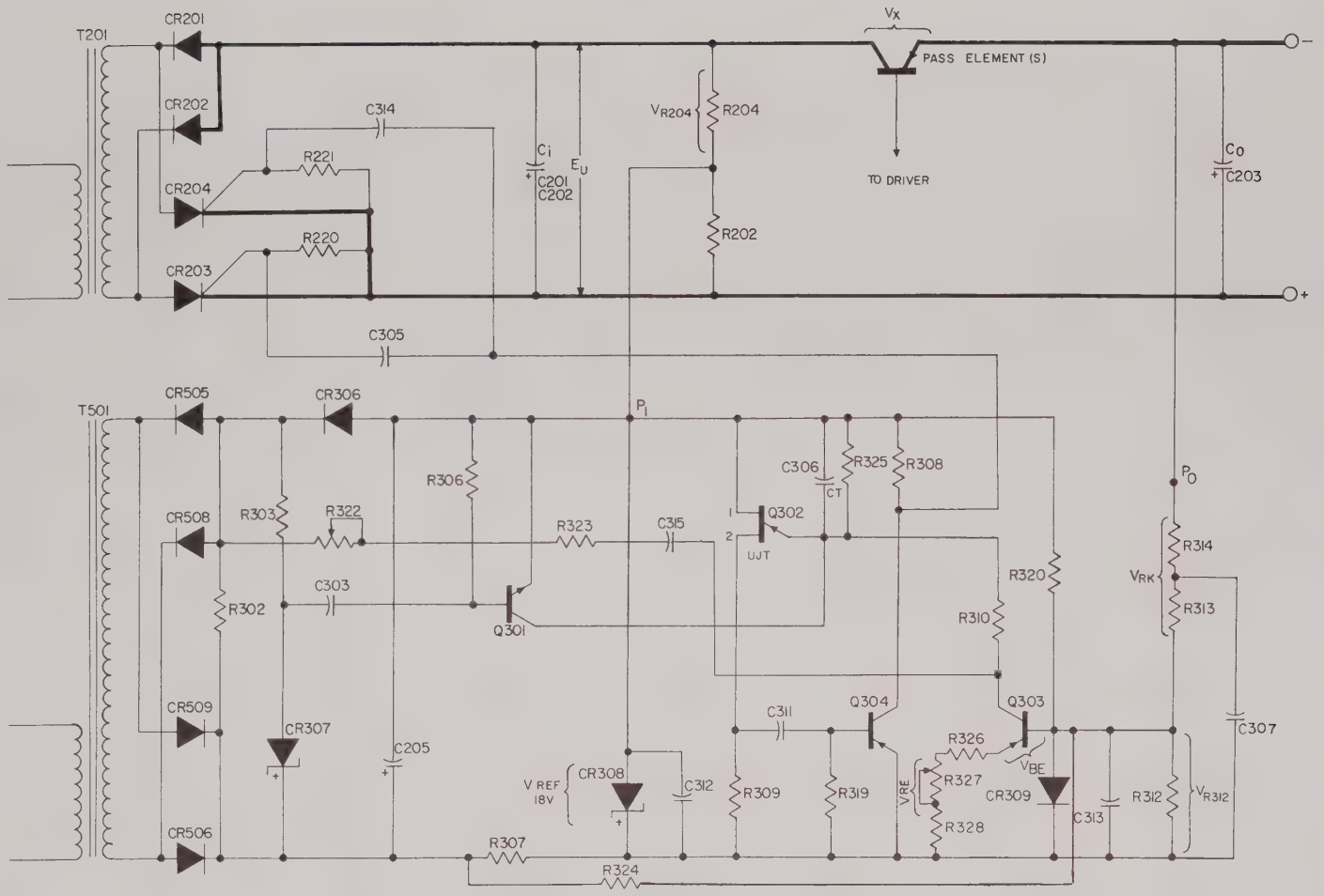
4-8 PRE-REGULATOR. The pre-regulator control circuit is located on PCB-2, assembly A3. The printed circuit board connector, P301, mates with main chassis plug J209. Pre-regulation is accomplished by controlling the conduction angle of the S.C.R. bridge rectifier to comply with the demand of the main regulator in such a manner as to minimize the power dissipated in the series pass elements. This does not mean that the voltage drop across the pass elements is held to a constant value, since maximum efficiency requires a fast-acting, low gain feedback system and reserve energy in the input capacitor (C_i) when output current demand is low, in order to avoid drop-out if maximum load is suddenly applied.

4-9 The transfer function of a capacitor-input, phase controlled rectifier system is non-linear with respect to both its input (AC Line) and output (DC) voltages. Linearization is achieved by the use of appropriate corrective input signals. The pre-regulator control circuit receives signals derived from: (A) the DC output voltage, (b) the input (line) voltage, (c) the load current and (d) the voltage drop across the series pass elements. It is the algebraic sum of all of these signals which controls the firing point of the silicon controlled rectifiers.

4-10 As may be seen in FIG. 4-5, the pass-element voltage (V_x) is algebraically added to a sample of the DC voltage across the input capacitor (C_i) and applied between points P_i and P_o. This voltage, offset by the voltage drop across Zener diode CR308, is divided down by the resistive network R312, R313 and R314 and applied to the base of transistor Q303. An adjustable resistance (R327) in the emitter circuit of Q303 sets the operating point. The collector current of Q303 charges capacitor C306 to the firing point of unijunction transistor Q302, which, on firing generates a pulse which is amplified by Q304 and delivered to both S.C.R. gates. Only one S.C.R. can have positive anode bias at any one time, and only this one will fire.

4-11 The transfer function of the feedback amplifier is such that, with the pass element voltage having been set at full current load, the pass voltage is allowed to rise a controlled amount when the load is removed, allowing reserve energy to be stored in the input capacitor Ci. This characteristic of the amplifier constitutes a virtual input proportional to load current. Corrective inputs proportional to the input line voltage are brought in (a) to the base of Q303 via R324 and (b) to the collector of Q303 via R322, R323 and C315. R322 is an adjustment which is used to offset the effects of component tolerance.

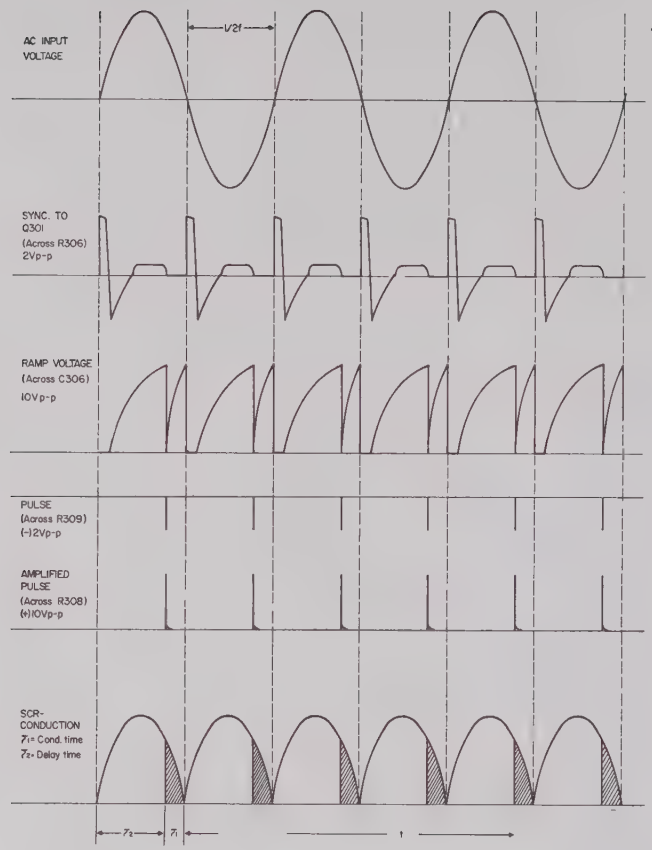
4-12 A timing pulse is generated at clipper diode CR307 which is fed to Q301. Conduction of Q301 discharges C306 completely, thus ensuring synchronization with the line frequency. C306 may be considered to be the summing point of all the inputs to the S.C.R. control circuit, since the slope of its charging curve determines the phase delay of the S.C.R. rectifiers. FIG. 4-6 illustrates typical circuit waveforms for two possible operating conditions.



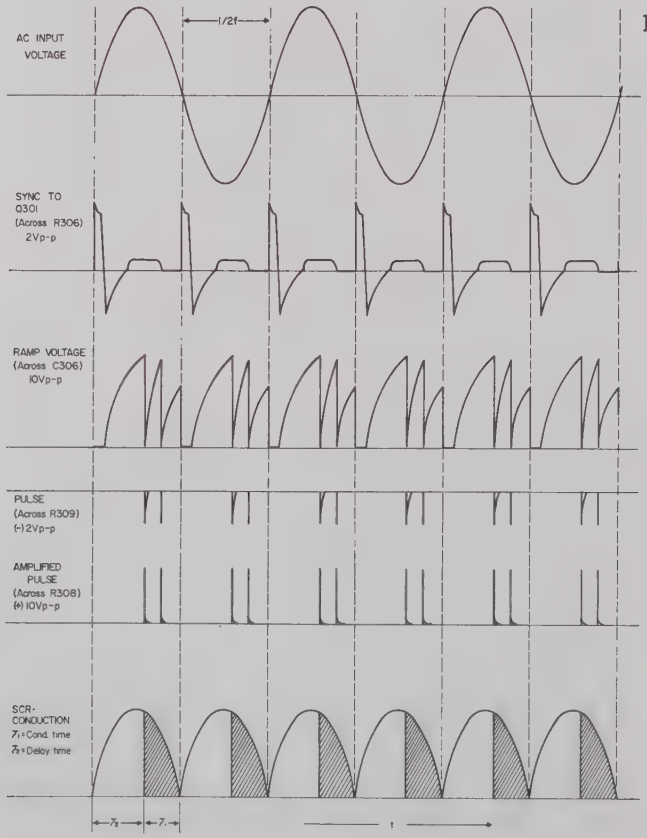
AT BALANCE:
- $(V_X + V_{RK}\ V_{R312}) = (V_{REF} + V_{R204})$
- $V_{R312} = (V_{RE} - V_{BE})$
- $V_{R204} \propto E_U$

C_T = TIMING RAMP CAPACITOR
C_I = INPUT CAPACITOR
C_O = OUTPUT CAPACITOR
E_U = UNREGULATED OUTPUT

FIG. 4-5 PRE-REGULATOR CIRCUIT SIMPLIFIED



A) SUPPLY VOLTAGE @ E_o max, NO LOAD



B) SUPPLY VOLTAGE @ E_o max, MAXIMUM LOAD

FIG. 4-6 SCR TIMING WAVE FORM

4-13 CONTROL SECTION (Refer to Fig. 4-7)

4-14 The control circuitry of the KS power supply is located on PCB-1, assembly A1. This assembly is in the form of a printed circuit board, whose connector P1 connects it to the main chassis and auxiliary circuitry through J202. (Refer to Fig. 4-1 & Fig. 4-2) Electrically the control circuitry consists of several interrelated sections which are described in detail below.

a) Control Circuit Power Supply. (Refer to Fig. 4-7) This highly regulated supply delivers the fixed operating voltages for the voltage mode and current mode amplifiers, as well as the reference voltages for the voltage mode and current mode comparison bridges. It is derived from a centertapped winding on T501 and consists of a full-wave rectifier with capacitor-input filter (CR503, CR504, C503), a series current regulator stage (Q1), and the zener regulator diodes CR10 and CR11 for the minus and plus 18 volts respectively. The negative and positive 18 volt supplies are filtered by C505 and C504 respectively. The voltage reference diode (CR14) is fed from the negative 18 V source and the current reference (CR15) from the positive 18 V source.

b) Comparison Bridges. In the Kepco KS power supplies two separate control channels are used, each with it's own comparison bridge circuit and its associated error signal amplifier. The voltage mode comparison bridge senses the output voltage across the output terminals of the power supply. (Except when using remote error sensing; then the bridge senses directly across the load.) The current mode comparison bridge senses the voltage across the current sensing resistor R_S. Each bridge compares its sensing voltage to its own reference voltage.

c) Current Mode Amplifier. An unbalance in the current mode comparison bridge results in an error signal which is transferred to input transistor Q10, and amplified by Q9 and Q13. It arrives at gate transistor Q5 as a large negative excursion.

d) Voltage Mode Amplifier. An unbalance in the voltage mode comparison bridge results in an error signal transferred to input transistor Q2 and is amplified by Q3. It arrives at the base of gate transistor Q4.

e) OR Gate. The gate transistors Q4 and Q5 act like a two pole switch. The transistor with the larger negative signal on its base will conduct, cutting the other one off. The transistor which conducts, be it Q4 or Q5, will in turn drive its associated mode-indicator amplifier companion into conduction, which then will energize either DS101 or DS102, the mode indicator.

f) Common Amplifier and Driver. The signal predominant in the above description, may it originate in the voltage or current mode comparison bridge, will be further amplified by Q7 and transferred to the pre-driver Q6 which, as an emitter-follower, supplies the necessary drive to the main-driver and the pass-elements.

g) Q8 is a bias-setting stage for the rest of the transistors in the amplifier. Its base provides a convenient point for the start of a dc analysis of the system.

h) Automatic Crossover Operation. Automatic mode switching in the KS power supplies is caused by an unbalance in one of the comparison bridges as discussed above. The operating mode of the power supply is therefore mutually dependent upon the load resistance and the setting of the voltage and current controls. The "Crossover Point" is defined by the ratio of the voltage and current setting which equals the load resistance. If for example, the load current due to a specific load resistance, is larger than the current control setting of the supply, the current mode comparison bridge will produce the larger error signal and the power supply will automatically switch to current mode operation as described above. At any load resistance value causing an output current smaller than the set value at the current control, the power supply will operate in voltage mode.

i) VIX Crossover Signals. Automatic Crossover from one mode of operation to the other is indicated by two signal lamps located on the front panel. (DS101, DS102). The crossover signal is also available at two jacks (J1, J2) on the rear of the unit. This signal may be taken out and converted into a heavy duty relay closure for signal purposes by means of the KEPCO VIX-1C Relay or any other device sensitive to a signal of ± 8V DC.(nominal), 1 ma.

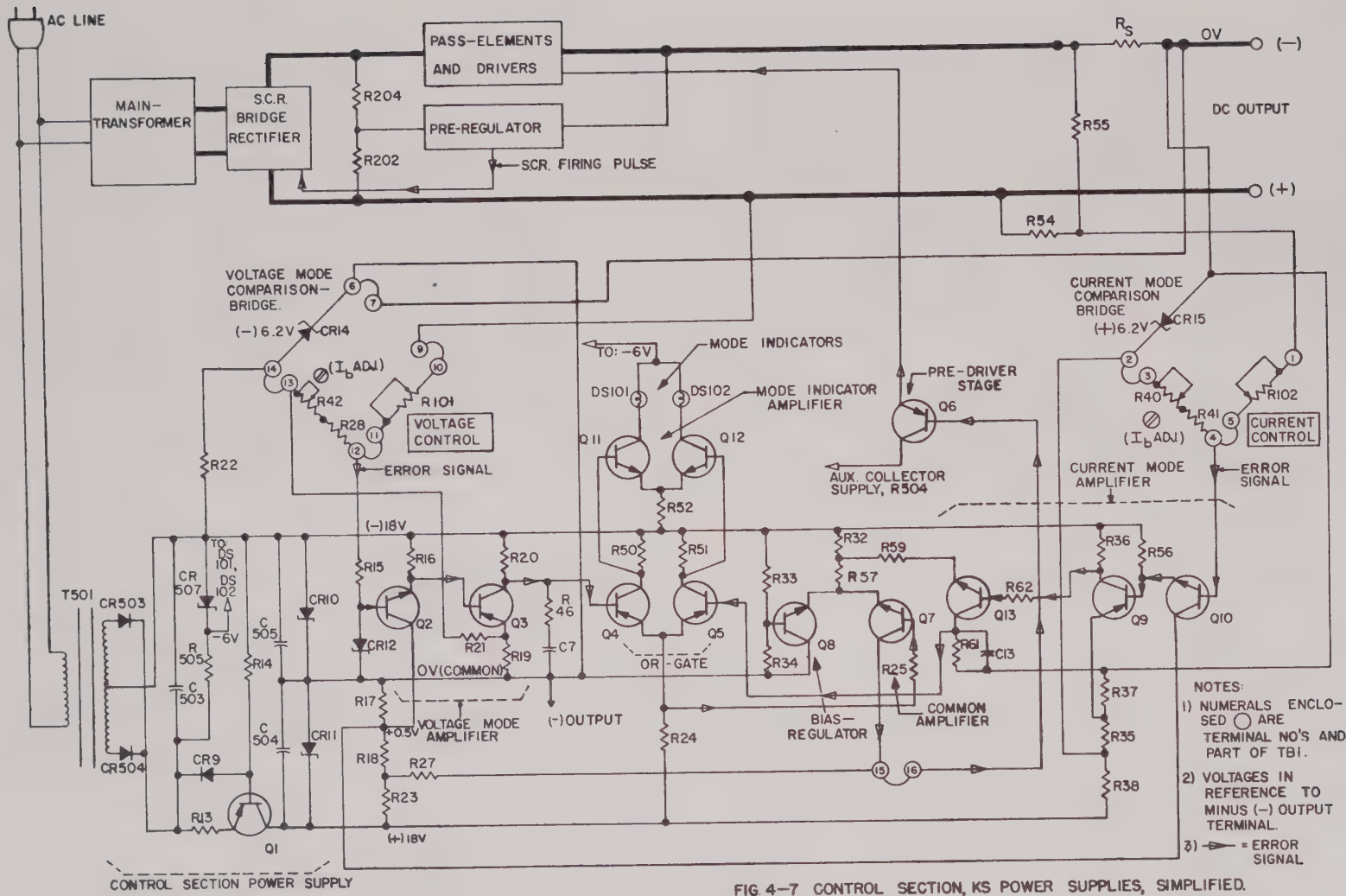


FIG. 4-7 CONTROL SECTION, KS POWER SUPPLIES, SIMPLIFIED.

SECTION V - MAINTENANCE

5-1 GENERAL

5-2 This section contains information for the maintenance, internal adjustments and test-measurements of the KEPCO Series KS Power Supply.

5-3 PRECAUTIONS

5-4 No part replacements or adjustments, other than described in this section, should be made on the instrument. Replacements or adjustments made without understanding the effects may cause serious damage to the Power Supply.

5-5 TEST EQUIPMENT REQUIRED

5-6 The following is a listing of the test equipment required to measure some important parameters and make all necessary adjustments on the KEPCO KS Power Supplies:

a) AC Line Step Device, or variable transformer capable of adjusting the power line from 105V to 125V AC and rated to deliver the maximum input current for the instrument under test. (Refer to Table 1-1).

b) Resistor load, adjustable to load the power supply to 10%, 50% and 100% in both, voltage and current operating modes and equipped with a shorting switch.

c) Voltage Monitor. Regulation Analyzer, differential or digital voltmeter with a resolution of at least 1 mV and a range covering the maximum output voltage of the power supply under test.

d) RMS reading voltmeter for ripple monitoring, Ballantine Model 320A or its equivalent.

e) Oscilloscope for monitoring SCR firing pulses and output ripple observance. (Tektronix, Model 502B or equivalent)

f) Multimeter for measuring pass element voltage and general trouble shooting measurements. 20K ohm/V, Weston Analyzer Model 980 or its equivalent.

g) Precision DC ampere meter with a range covering the maximum output current of the Model under test. (Weston Model 931 or equivalent)

5-7 DISASSEMBLY (Refer to Fig. 1-3)

5-8 Internal adjustments on the KS power supplies may require partial disassembly of the unit. This is readily accomplished by following the steps given below. Proceed in reverse order for re-assembly.

a) Top Cover Plate. Held by six (6) Phillips-head 6/32 machine screws. Loosen screws and remove plate.

b) Side Carrying Handles (on 8 3/4" high units only). Held by eight (8) Phillips-head 10/32 machine screws each. Loosen screws and remove handles.

c) Skid Rails (on 8 3/4" high units only). Held by three (3) flat head 10/32 machine screws on each side of case bottom. Loosen screws and remove rails and stand-offs.

d) Bottom Cover. (on 8 3/4" high units, removal possible only after skid rails have been dismounted). Held by six (6) Phillips-head 6/32 machine screws. Loosen screws and remove plate.

e) Rear Cover. Held by eight (8) Phillips-head 6/32 machine screws. Loosen screws and remove cover plate.

5-9 INTERNAL ADJUSTMENT PROCEDURES

5-10 The internal adjustments for maximum output current and voltage are located on assembly A1 as shown in Fig. 2-3 and Table 2-2. These adjustments vary the bridge current (I_b) in both, voltage and current comparison bridge. They are factory adjusted to a value 2% above the maximum rated voltage or current with the respective front panel controls fully clockwise. These controls require resetting only if previously changed for programming purposes or following replacement of related circuit components.

5-11 PROCEDURE, VOLTAGE CONTROL ADJUSTMENT

a) Remove top and rear cover plates by loosening holding screws. (Refer to Paragraph 5-7)

b) Connect precision voltmeter of suitable range across the front or rear output terminals of the power supply. Turn both voltage and current front panel controls to their maximum clockwise position.

c) Turn power supply "on". Locate R42 "Maximum Voltage Control" on Assembly A1, (Fig. 2-3), and adjust output voltage to 2% above maximum rated value for the particular model, as observed on the external, precision voltmeter.

d) Replace cover plates and holding screws.

5-12 PROCEDURE, CURRENT CONTROL ADJUSTMENT (See also par. 3-19)

a) Remove top and rear cover-plates by loosening holding screws. (Refer to Paragraph 5-7).

b) Connect a precision ampere meter of suitable range across the rear output terminals of the supply. Turn the front panel voltage control to its maximum clockwise, and the front panel current control to its maximum counter clockwise position.

c) Turn power supply "on", and slowly turn the front panel current control clockwise until its maximum clockwise position is reached.

d) Locate "Maximum Current Adjust" control on assembly A1 (Refer to Fig. 2-3) and adjust output current to 2% above its maximum rated value for the particular model, as observed on the external precision ampere meter.

e) Replace cover plates and holding screws.

NOTE: The following internal adjustments are precision factory set and should not be altered unless required by replacement of components associated with the controls.

5-13 PROCEDURE, INTERNAL AMMETER CALIBRATION (Applicable on metered units rated for an output current rating greater than 15A DC. On unmetered units and units with an output current of 15A DC and smaller, R215 is deleted.)

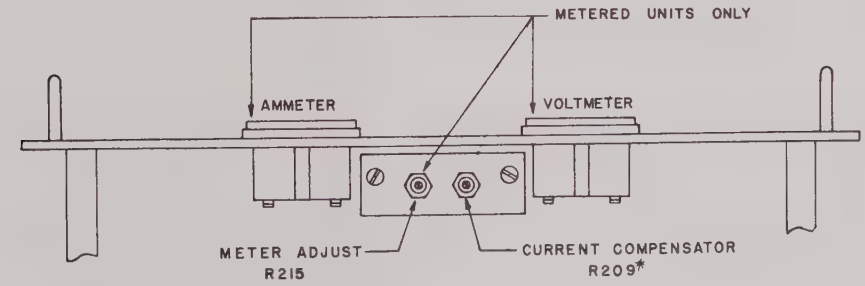


FIG. 5-1 LOCATION OF AMMETER CALIBRATION RESISTOR AND CURRENT COMPENSATOR

a) Remove top and rear cover plates by loosening holding screws as indicated in Paragraph 5-7.

b) Turn Current Control on the front panel to its maximum counter clockwise position.

* R208 on some models.

c) Connect precision ampere meter across the rear output terminals of the power supply.

d) Turn power supply "on" and slowly advance the Current Control clockwise until maximum output current is reached.

e) Compare panel meter reading with the precision meter readings and correct for discrepancies by loosening lock-nut on R215 (Refer to Fig. 5-1) and adjusting it to the desired value. Relock R215.

5-14 PROCEDURE, CURRENT REGULATION COMPENSATOR ADJUSTMENT

5-15 Potentiometer R208*in conjunction with its associated components (R209* R54, R55) compensates for the internal loading of the voltmeter and the voltage bridge circuit when the power supply is operating in the constant current mode. Adjustment of this control is required only when it or its associated components must be replaced or when other changes of internal loading of the power supply take place.

a) Equipment Required: (Refer to Paragraph 5-5)

b) Connect test equipment as shown in Fig. 5-5.

c) With the power supply in its current regulation mode, and drawing approximately 10% of its maximum load current, measure the voltage drop across R_S.

d) Close S-1 and note delta V, the difference between the readings with S-1 open and closed. Rotate R208 as to minimize delta V on repeated tests.

5-16 PROCEDURE, PRE-REGULATOR ADJUSTMENTS

5-17 Replacement of parts in the pre-regulator section of the power supply may necessitate the readjustment of the two controls in this section.

a) Instruments Required: (Refer to Paragraph 5-5)

b) Connect the resistor load to the rear-output terminals of the power supplies. (Refer to Fig. 5-6)

c) Connect multimeter and oscilloscope as indicated in Fig. 5-2. (Main-Chassis Component Location).

CAUTION: To avoid ground loop shorting effects, use differential input connection on the oscilloscope.

*Reference designations R208 and R209 are interchanged on some units.

d) Connect power supply to the variable transformer or line step device and adjust AC input to 105V AC.

e) Refer to FIG. 2-3. Locate R322, "Line Voltage Feedback Adjust" and set the control completely counter clockwise. Locate R327, "Maximum Pass Voltage Adjust" and set the control to its approximate mid-position.

f) Turn Power Supply "on". Set to maximum rated output voltage (No load connected).

g) Read voltage across pass-elements (V_X) on the multimeter, and set to approximately 8 volts, by adjusting R311.

h) Connect load to the output, so that maximum rated output current is drawn. Again, read the pass-element voltage (V_X) and adjust R327 until the multimeter reads 3 volts.

i) Vary AC input voltage to 125V AC and observe the voltage change (ΔV_X) on the multimeter. If ΔV_X is greater than 1.5 V, adjust the "Line Voltage Feedback Adjust" (R322) so that ΔV_X is smaller than 1 volt for AC input voltage changes from 150V AC to 125V AC.

j) Check for minimum pass voltage at 105V AC line and re-adjust to 3 volts, since some interaction between the two previous adjustments takes place. Simultaneously with the adjustment, observe the oscilloscope. With the scope "Sync. Control" in the "Line" position, a regular, stable series of S.C.R. firing pulses whih a repetition rate of 120 Hz should be seen. Turn power "off".

k) Place a short circuit across the power supply (wire size appropriate for the maximum current rating): Turn "Current Control" at the front panel counter clockwise. Turn supply "on" and adjust "Current Control" for maximum rated output current.

l) Observe S.C.R. firing pluses and ΔV_X as the AC input is varied between 105V AC and 115V AC. V_X as well as ΔV_X should be not more than 30% higher as previously observed in the voltage mode of operation. Firing pulses must be of the same repetition rate and stable. This concludes the pre-regulator adjustment.

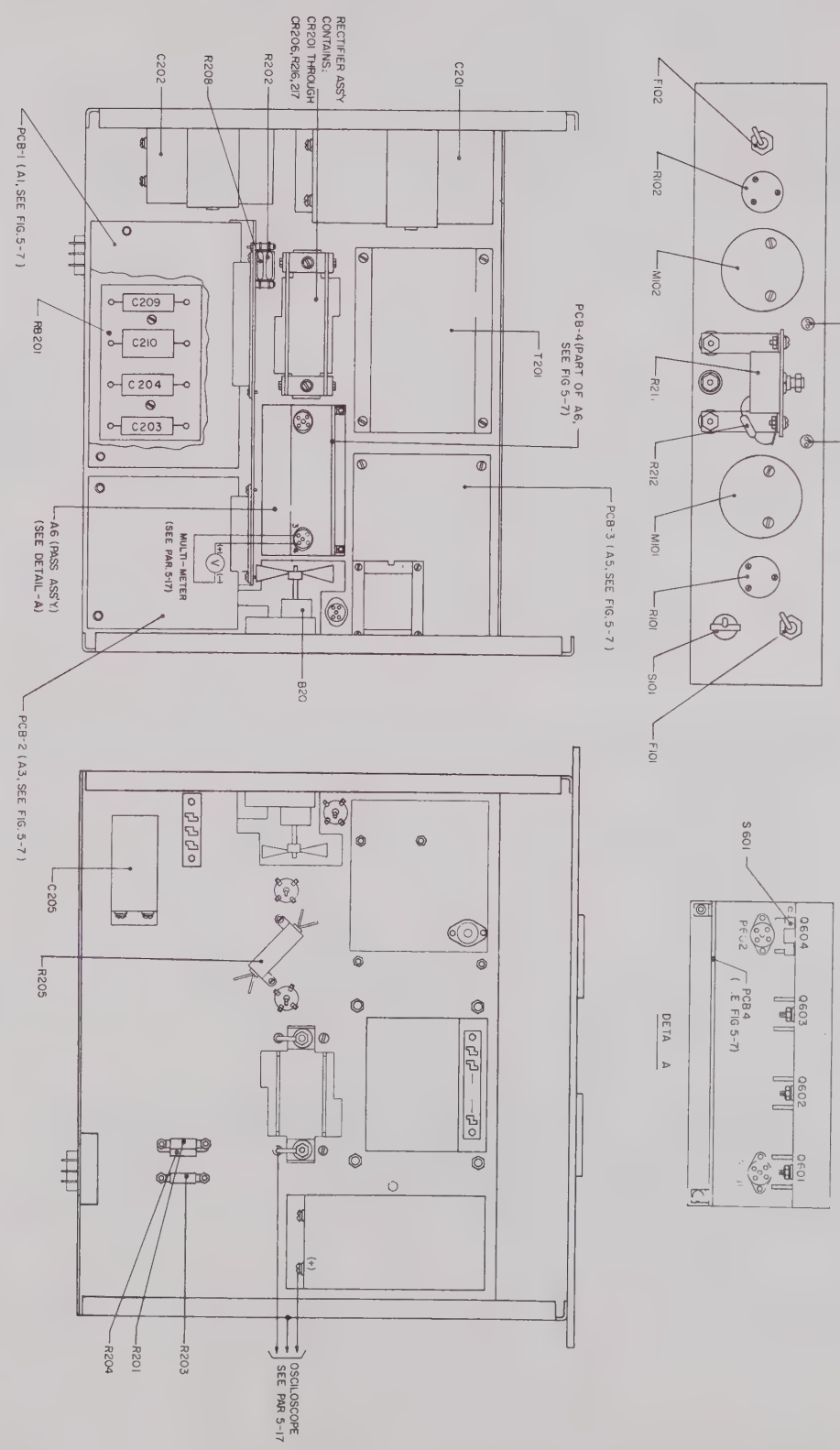


FIG. 5-2 COMPONENT LOCATION, MAIN CHASSIS ASSEMBLY (A-2)

5-18 TROUBLE SHOOTING

5-19 Contrary to popular opinion, modern, high performance power supplies today have reached a state of sophistication that requires thorough understanding of the problems involved in repairing complex, solid state circuitry. Servicing beyond simple parts replacements should consequently be attempted only by personnel thoroughly familiar with solid state component techniques and with experience in closed loop circuitry.

5-20 Trouble-shooting charts, showing resistance and voltage readings, are of very limited usefulness with feedback amplifiers and are not included here. Instead a detailed circuit description (Section IV), parts location diagrams, simplified functional schematics of the several circuit sections, and a main schematic with all significant voltage readings is presented.

5-21 The following basic steps in a case of power supply malfunctioning may also be found useful:

a) If power supply does not function at all: Check all powerline connections and fuses and make certain, power supply is connected to the correct line voltage (it is normally delivered for 115V AC operation).

b) If power supply fuses keep blowing or circuit breakers keep tripping, check pass-elements (without removing from assembly) by placing an ohm-meter across the emitter and collector. The emitter-collector resistance will be low in one direction and higher in the other, the ratio being approximately 5:1. If resistance is equally low in both directions (short circuit) the pass-element must be replaced.

c) If the power supply is basically functioning, but poor performance is evident, inspect the test set-up to make certain the source of the trouble is not external.

d) Poor regulation in any of the regulating modes is usually traceable to incorrectly connected loads or faulty measurement techniques. Perform measurements as described in Paragraph 5-23 and follow the connecting diagrams.

e) Oscillation of the output voltage or output current is often due to a load with a large inductive component. Twisted loadwires of sufficient diameter and held as short as practical, are often the solution to the problem. In severe cases, a capacitor directly across the load will frequently help.

5-22 KEPCO Field Engineering Offices or the KEPCO Repair Department will be available for consultation or direct help in difficult service or application problems.

5-23 POWER SUPPLY MEASUREMENTS

5-24 Measurement of the significant parameters of a power supply is a requirement for incoming inspection, periodic maintenance, or after component replacement. Since some of the measurements require special techniques to insure correct results, suggestions for their performance are given below:

a) Instrumentation

Refer to Paragraph 5-5 for the necessary test equipment.

b) The proper location of the instrument leads when measuring regulation is of the utmost importance. Improperly placed leads may measure voltage drop due to contact resistance and load current flow and thus lead to incorrect results. This can be avoided by the four terminal network technique. Fig.s 5-3 to 5-6 show clearly how this technique is employed in regulation measurements. The principle is very simple but important: Do not measure voltage drops due to load current.

c) Voltage Regulation is defined as the amount of output voltage change resulting from a specified change in line voltage or from a change in load resistance. It can be expressed as an absolute change (ΔE_o)or as a percentage in reference to the total output voltage E_o;

$$\% \text{ Voltage Regulation} = \frac{\Delta E_o}{E_o} \text{ X } (100\%)$$

d) Current Regulation is defined as the amount of output current change resulting from a specified change in line voltage or from a change in load resistance. It can be expressed as an absolute change (ΔI_o), or as a percentage in reference to the total output current I_o;

$$\% \text{ Current Regulation} = \frac{\Delta I_o}{I_o} \text{ X } (100\%)$$

e) Ripple. An oscilloscope of suitable sensitivity, or a true RMS indicating meter may be used to measure the ripple at the output of the power supply. Suitable DC blocking must be provided externally, if the test instrument is not equipped with a suitable input. A 0.1 mfd capacitor of sufficient working voltage is generally adequate. If an oscilloscope is used only, the p-p/rms ratio, which

for a pure sine wave is close to 2.83:1, can be approximated for the broken wave-form of a series regulator type power supply as 3:1.

CAUTION: Due to the low signal levels, ripple pick-up problems are especially accute when measuring ripple in the current mode. The use of completely shielded sensing resistors and load cables may be necessary to get valid readings.

The observed ripple current will depend, to some extent, upon the compliance (load) seen by the Power Supply when measurement is made. Specifically, the observed current ripple will show a slight increase when the load impedance is made so small as to approach the filter capacitor's reactive impedance. Under such circumstances, the filters are ineffective because they are "shorted" by the load.

This effect will have little influence upon normal operation of the Power Supply because the impedance of the load-connecting wires is usually sufficient to prevent the "shorting effect." (It will probably be noticed only when extremely small "crowbar" short-circuit loads are employed, as in testing.) For specification purposes, the minimum compliance voltage for ripple measurements is set at 0.5V DC.

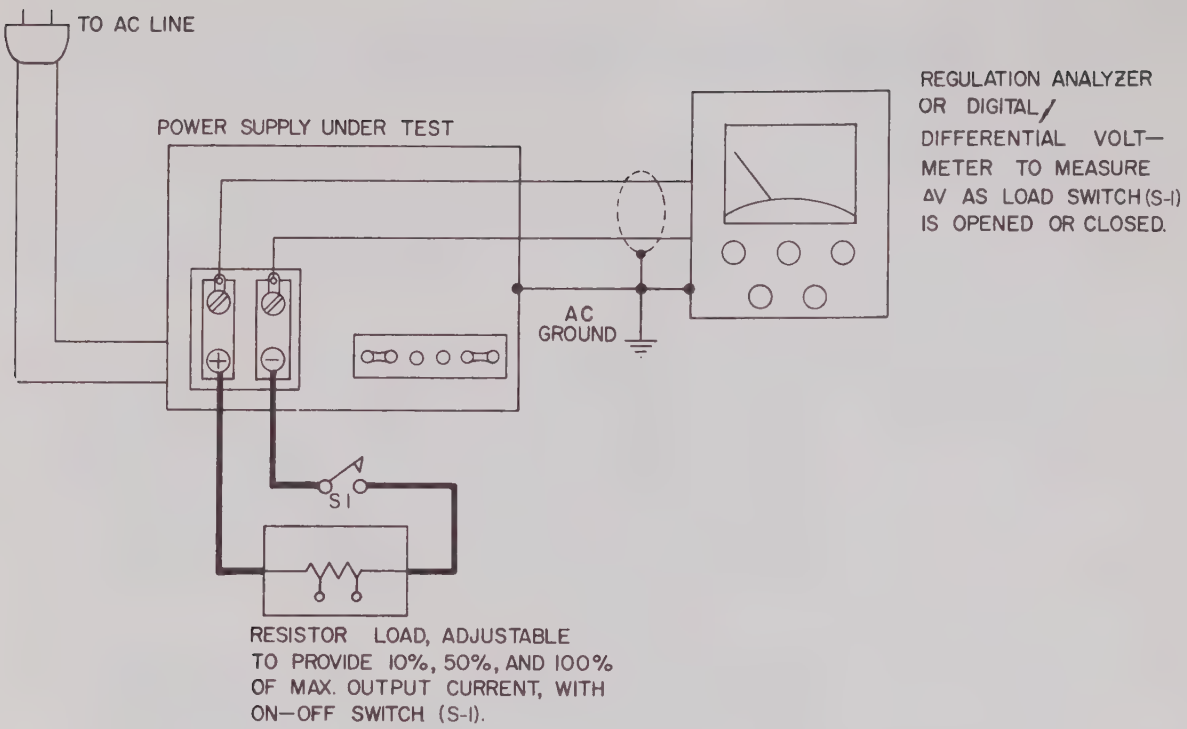

TO AC LINE
POWER SUPPLY UNDER TEST
REGULATION ANALYZER OR DIGITAL/ DIFFERENTIAL VOLT— METER TO MEASURE ΔV AS LOAD SWITCH (S-1) IS OPENED OR CLOSED.
AC GROUND
S1
RESISTOR LOAD, ADJUSTABLE TO PROVIDE 10%, 50%, AND 100% OF MAX. OUTPUT CURRENT, WITH ON—OFF SWITCH (S-1).

FIG. 5-3 MEASURING LOAD REGULATION (VOLTAGE MODE) WITHOUT REMOTE ERROR SENSING

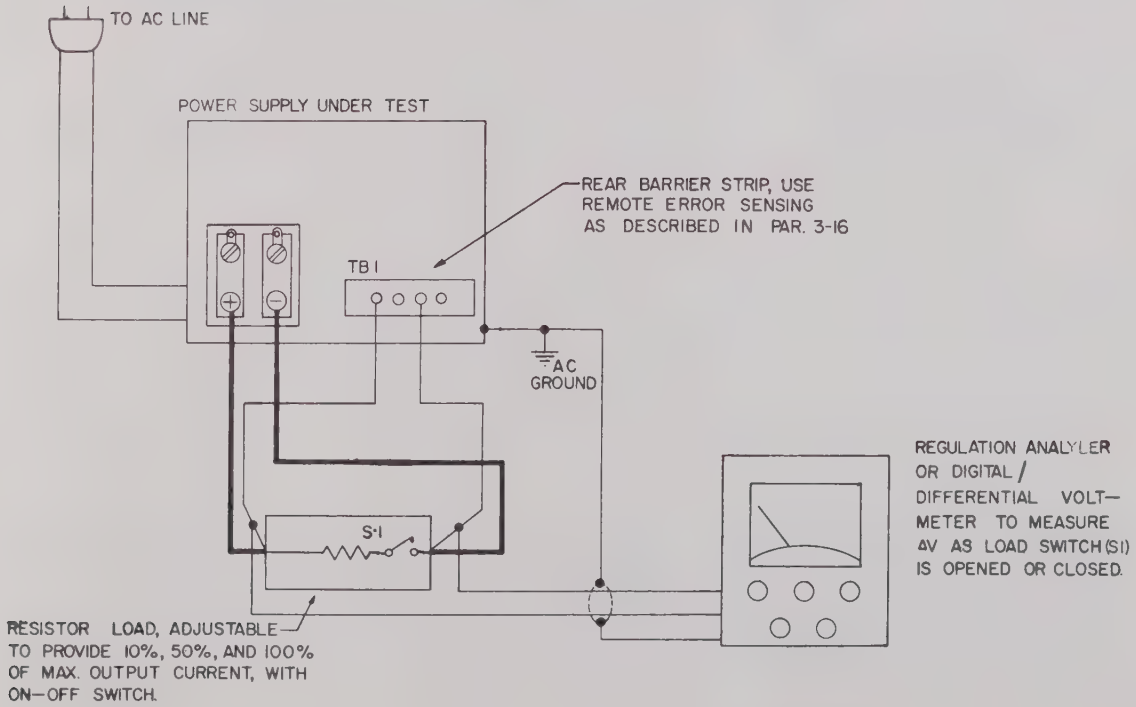

TO AC LINE
POWER SUPPLY UNDER TEST
REAR BARRIER STRIP, USE REMOTE ERROR SENSING AS DESCRIBED IN PAR. 3-16
TB1
AC GROUND
S-1
REGULATION ANALYLER OR DIGITAL/ DIFFERENTIAL VOLT— METER TO MEASURE ΔV AS LOAD SWITCH (S1) IS OPENED OR CLOSED.
RESISTOR LOAD, ADJUSTABLE TO PROVIDE 10%, 50%, AND 100% OF MAX. OUTPUT CURRENT, WITH ON—OFF SWITCH.

FIG. 5-4 MEASURING LOAD REGULATION (VOLTAGE MODE) DIRECTLY AT THE LOAD

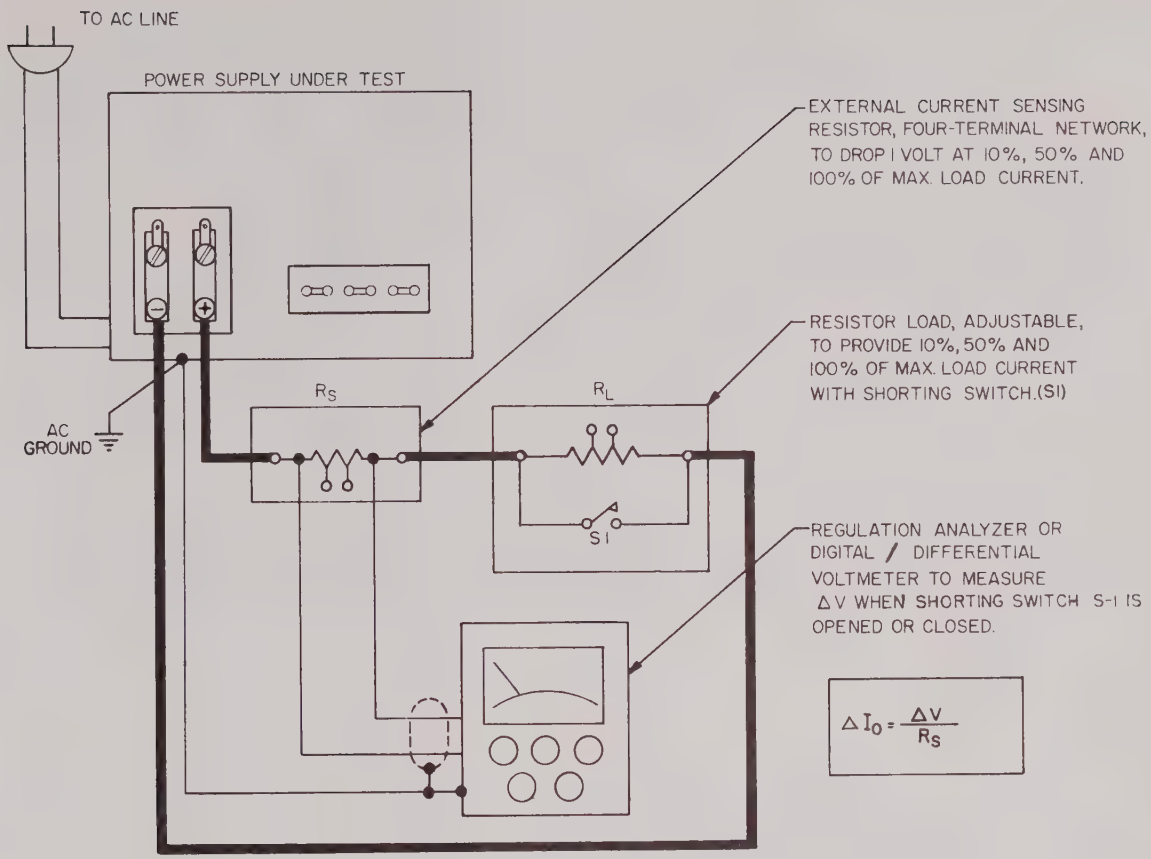

TO AC LINE
POWER SUPPLY UNDER TEST
EXTERNAL CURRENT SENSING RESISTOR, FOUR-TERMINAL NETWORK, TO DROP 1 VOLT AT 10%, 50% AND 100% OF MAX. LOAD CURRENT.
RESISTOR LOAD, ADJUSTABLE, TO PROVIDE 10%, 50% AND 100% OF MAX. LOAD CURRENT WITH SHORTING SWITCH.(SI)
R_S
R_L
AC GROUND
S1
REGULATION ANALYZER OR DIGITAL / DIFFERENTIAL VOLTMETER TO MEASURE ΔV WHEN SHORTING SWITCH S-1 IS OPENED OR CLOSED.
$\Delta I_O = \frac{\Delta V}{R_S}$

FIG. 5-5 MEASURING LOAD REGULATION (CURRENT MODE)

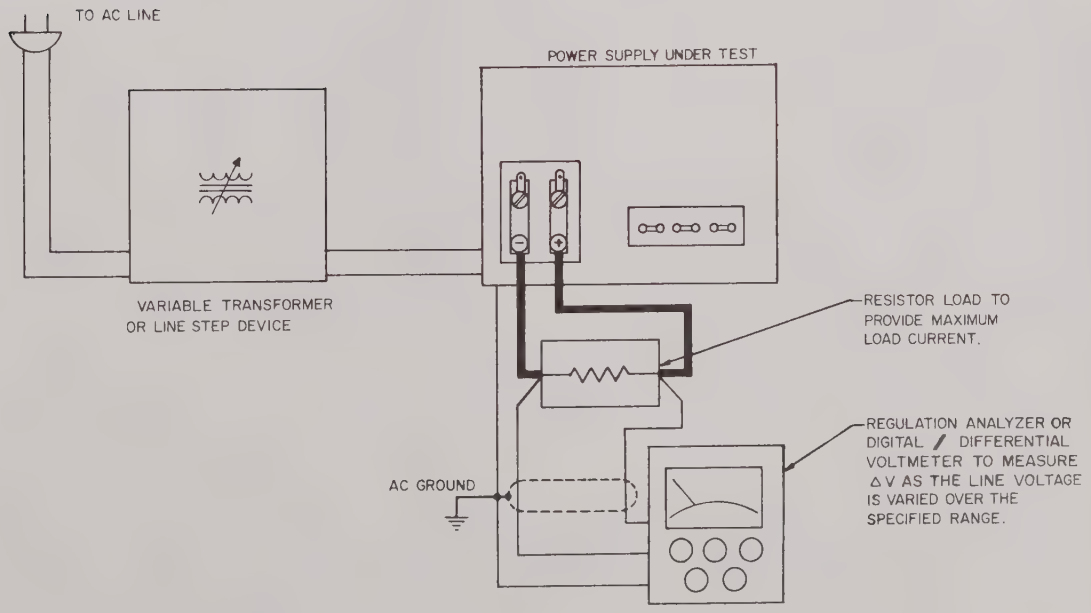
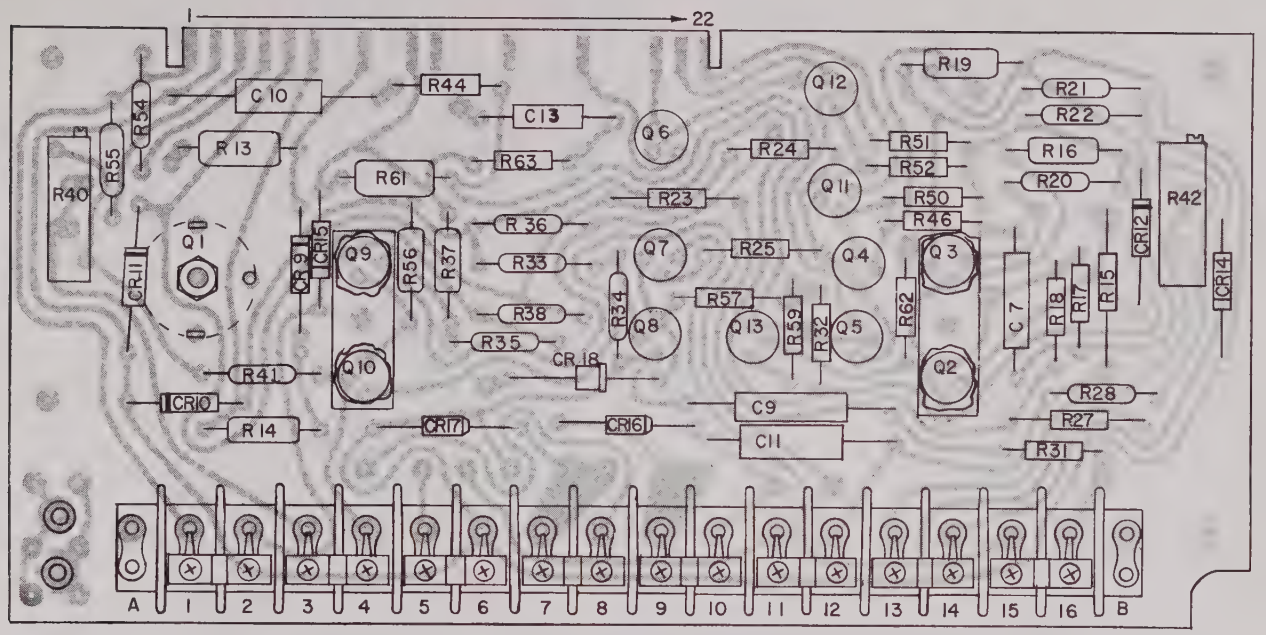
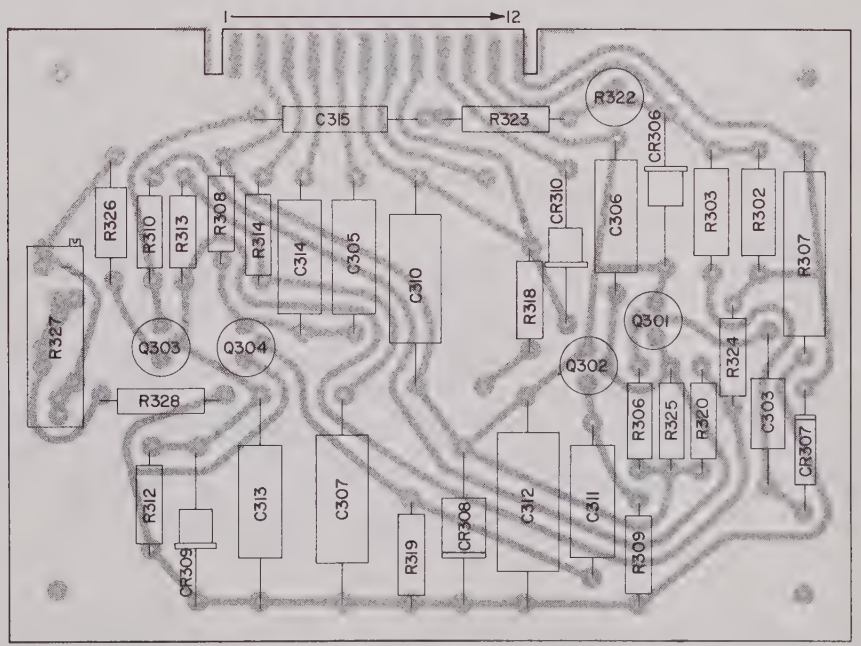

TO AC LINE
POWER SUPPLY UNDER TEST
VARIABLE TRANSFORMER OR LINE STEP DEVICE
RESISTOR LOAD TO PROVIDE MAXIMUM LOAD CURRENT.
REGULATION ANALYZER OR DIGITAL / DIFFERENTIAL VOLTMETER TO MEASURE ΔV AS THE LINE VOLTAGE IS VARIED OVER THE SPECIFIED RANGE.
AC GROUND

FIG. 5-6 MEASURING LINE REGULATION (VOLTAGE MODE)



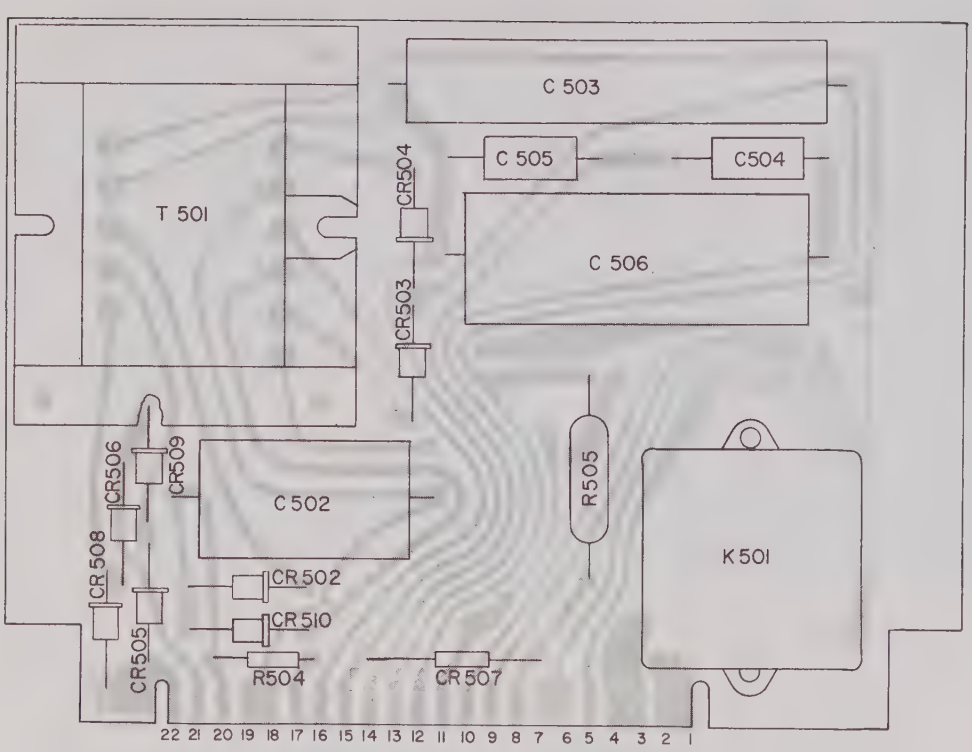
A) ASSEMBLY A1, PCB 1



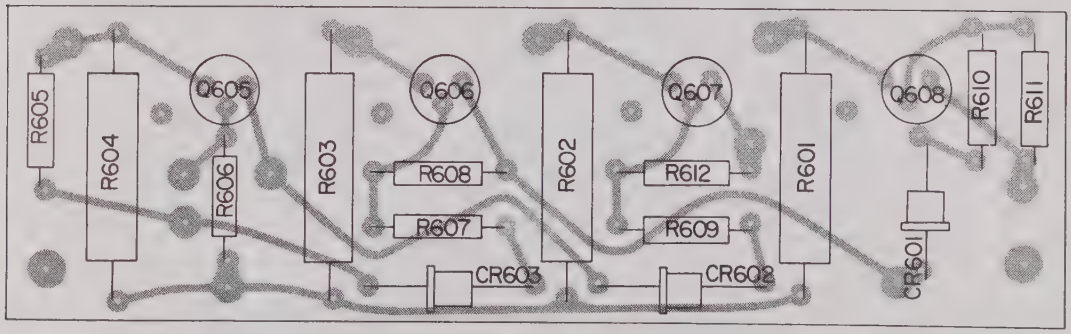
B) ASSEMBLY A3, PCB 2

FIG. 5-7 COMPONENT LOCATION, PRINTED CIRCUIT BOARDS

A) ASSEMBLY A1
B) ASSEMBLY A3
C) ASSEMBLY A5
D) ASSEMBLY A6

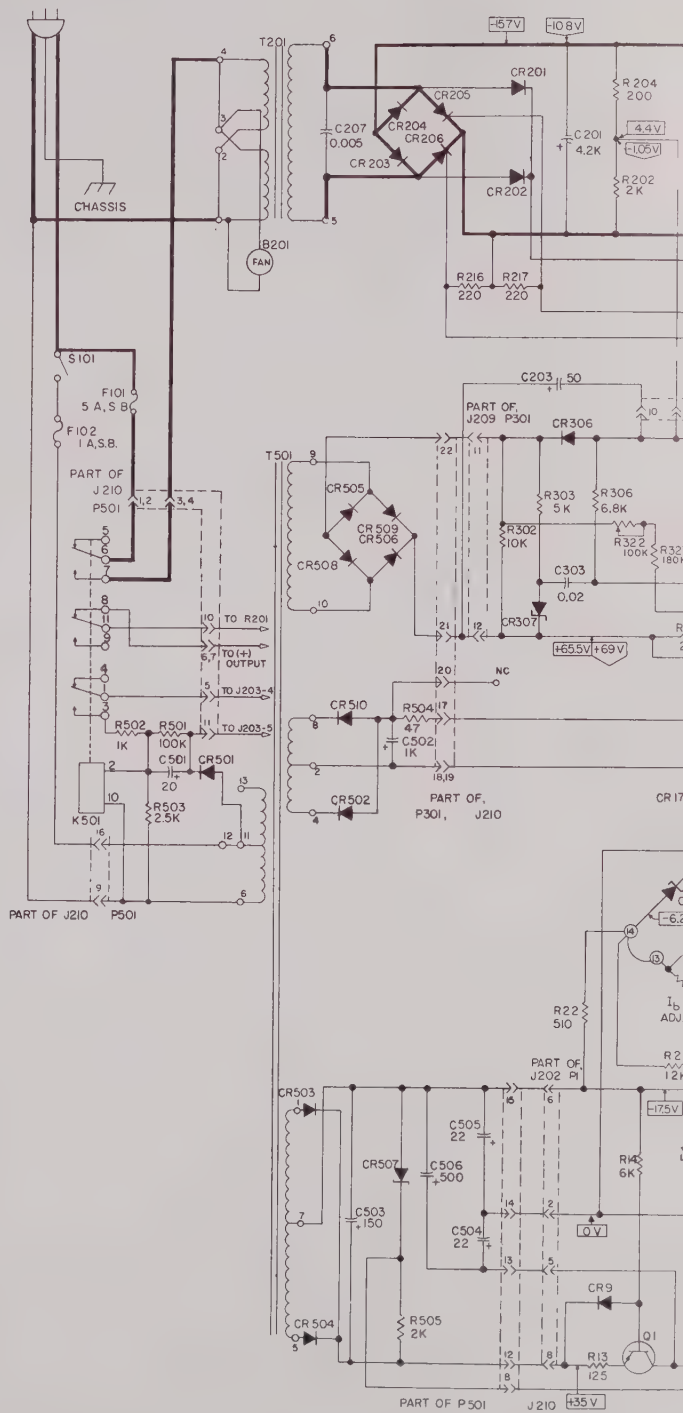


C) ASSEMBLY A5, PCB 3



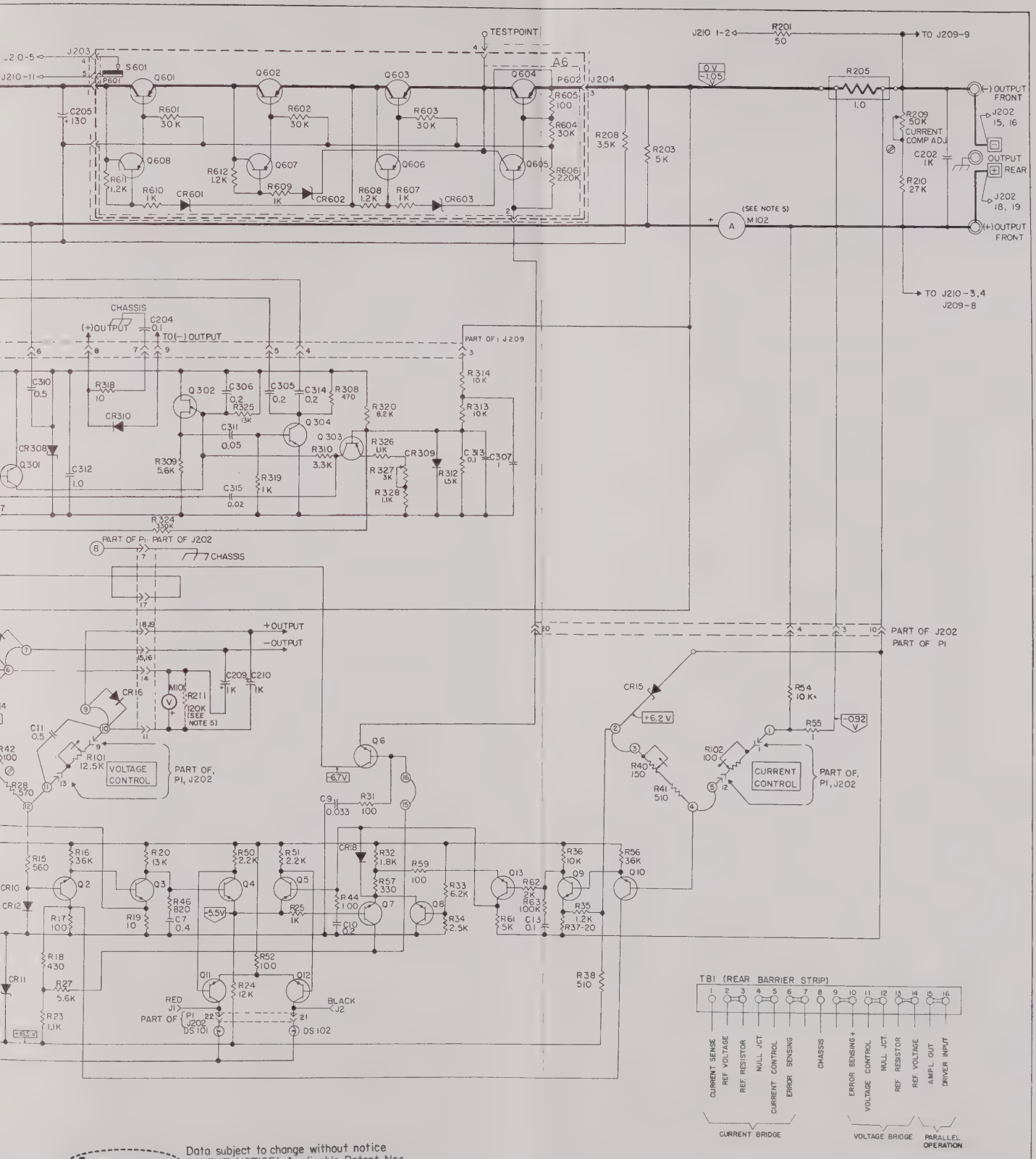
D) ASSEMBLY A6, PCB 4

EM06105 2-8-68



NOTES:

1. K501 IS A PLUG-IN TYPE RELAY, WITH AN 11 PIN PLUG. THE NUMBERS REPRESENT PIN NUMBERS.
2. ALL RESISTOR VALUES ARE IN OHMS, K=1,000.
   ALL CAPACITOR VALUES ARE IN MICROFARADS, K=1,000.
3. VOLTAGE READINGS IN RECTANGLES (▭) ARE TYPICAL VALUES FOR VOLTAGE MODE OPERATION WITH AC LINE AT 115V, DC OUTPUT VOLTAGE SET TO MAXIMUM, AND AT NO LOAD MEASUREMENTS REFERRED TO (-) OUTPUT TERMINAL.
4. VOLTAGE READINGS IN (S)IDED SYMBOLS (⬭) ARE TYPICAL VALUES FOR CURRENT MODE OPERATION AT MAXIMUM OUTPUT VOLTAGE AND CURRENT. MEASUREMENT REFERRED TO (-) OUTPUT TERMINALS.
5. M101, M102, ARE USED IN METERED UNITS ONLY. R211 IS USED IN UNMETERED UNITS ONLY.
6. ORDER REPLACEMENT PARTS BY KEPCO PART NUMBER. SEE PARTS LIST.
7. VOLTAGE READINGS WHICH APPLY TO NOTES 3 & 4 ARE TYPICAL AND SUBJECT TO COMPONENT TOLERANCES.



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Data subject to change without notice
PATENT NOTICE: Applicable Patent Nos. will be supplied on request.

FIG. 5-8 MAIN SCHEMATIC, MODEL KS 120-1

kepco inc. ® REPLACEMENT PARTS LIST

AMPLIFIER BOARD, PCB#1, ASS'Y A1, MODEL KS120-1(M) Code 8-1166

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C7	1	Capacitor, Mylar, Pigtail 0.4 µF, 200 V, 10%	Wesco Type 33MM	117-0128
C9	1	Capacitor, Mylar, Pigtail 0.033 µF, 200 V, 10%	Sprague 192P33392	117-0347
C10	1	Capacitor, Mylar, Pigtail 0.2 µF, 200 V, 10%	TRW Type X663F	117-0236
C11	1	Capacitor, Mylar, Pigtail 0.5 µF, 200 V, 10%	TRW Type X663F	117-0123
C13	1	Capacitor, Mylar, Pigtail 0.1 µF, 200 V, 10%	Sprague 192P10492	117-0363
CR9,12	2	Zener Diode	IRC AN267	121-0028
CR10,11	2	Zener Diode	Motorola 1N3026B	121-0036
CR14,15	2	Zener Diode	IRC 1N821	121-0041
CR16,17	2	Rectifier, Silicon, Pigtail	Solitron HVP	124-0178
CR18	1	Rectifier, Silicon, Pigtail	Semicon SM-110	124-0133
Q1	1	Transistor, Silicon, PNP	Delco 2N174	119-0016
Q2,7,8, 10,11,12,13	7	Transistor, Silicon, NPN	General Electric 2N338	119-0054
Q3,4,5, 6,9	5	Transistor, Silicon, PNP	Hughes 2N1131A	119-0055
R13	1	Resistor, Fixed, Power, Axial 125 ohm, 3 W, 3%	Tepro TS3C	115-1467
R14	1	Resistor, Fixed, Power, Axial 6 K ohm, 3 W, 5%	Hardwick Hindle 9/16 GA 6K LTC 3%	115-1155
R15	1	Resistor, Fixed, Molded 560 ohm, 1/2 W, 10%	Allen Bradley EB5611	115-0451
R16,56	2	Resistor, Fixed, Precision, WW 36 K ohm, 2 W, 5%	Tepro TS2C	115-1313
R17,52, 31,59,63	5	Resistor, Fixed, Molded 100 ohm, 1/2 W, 10%	Allen Bradley EB1011	115-0626
R18	1	Resistor, Fixed, Molded 430 ohm, 1/2 W, 5%	Allen Bradley EB4315	115-0581
R19,37	2	Resistor, Fixed, Precision, WW 10 ohm, 3 W, 5%	Tepro TS3C	115-0421
R20	1	Resistor, Fixed, Power, Axial, WW 13 K ohm, 1 W, 5%	Tepro TS1W	115-1309

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

kepco inc.® REPLACEMENT PARTS LIST

AMPLIFIER BOARD, PCB#1, ASS'Y A1, MODEL KS 120-1(M) Code 2-868

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R21,35	2	Resistor,Fixed,Precision,WW 1.2 K ohm, 1 W, 5%	Tepro TS1W	115-1306
R22,38, 41	3	Resistor,Fixed,Precision,WW 510 ohm, 1 W, 1%	Tepro TS1W	115-1466
R23	1	Resistor,Fixed,Molded 1.1 K ohm, 1 W, 5%	Allen Bradley GB1125	115-0545
R24	1	Resistor,Fixed,Molded 12 K ohm, 1/2 W, 10%	Allen Bradley EB1231	115-1168
R25	1	Resistor,Fixed,Molded 1 K ohm, 1/2 W, 5%	Allen Bradley EB1021	115-0547
R27	1	Resistor,Fixed,Molded 5.6 K ohm, 1/2 W, 10%	Allen Bradley EB5621	115-1201
R28	1	Resistor,Fixed,Precision,WW 570 ohm, 1 W, 1%	Tepro TS1W	115-1465
R32	1	Resistor,Fixed,Molded 1.8 K ohm, 1/2 W, 10%	Allen Bradley EB1821	115-0473
R33	1	Resistor,Fixed,Precision,WW 6.2 K ohm, 1 W, 5%	Tepro TS1W	115-1335
R34	1	Resistor,Fixed,Precision,WW 2.5 K ohm, 1 W, 5%	Tepro TS1W	115-1307
R36,54	2	Resistor,Fixed,Power,Axial 10 K ohm, 3 W, 5%	Tepro TS3C	115-0460
R37	1	Resistor,Fixed,Power,Axial 20 ohm, 3 W, 5%	Tepro TS3C	115-0851
R40	1	Resistor,Variable 150 ohm, 1/2 W, 10%	Bourns 3067P-1-151	115-1534
R42	1	Resistor,Variable 100 ohm, 1/2 W, 10%	Bourns 3067P-1-101	115-1434
R44	1	Resistor,Fixed,Molded 180 ohm, 1/2 W, 5%	Allen Bradley EB1815	115-0807
R46	1	Resistor,Fixed,Molded 820 ohm, 1/2 W, 5%	Allen Bradley EB8215	115-0956
R50,51	2	Resistor,Fixed,Molded 2.2 K ohm, 1/2 W, 10%	Allen Bradley EB2221	115-0466
R55	1	Resistor,Fixed,Precision,WW 1 ohm, 1 W, 1%	Tepro TS-1W	115-1361
R57	1	Resistor,Fixed,Molded 330 ohm, 1/2 W, 10%	Allen Bradley EB3311	115-0804
R61	1	Resistor,Fixed,Power,Axial 5 K ohm, 3 W, 5%	Hardwick Hindle 9/16 GA-5000 LTC	115-1094
R62	1	Resistor,Fixed,Molded 2 K ohm, 1/2 W, 5%	Allen Bradley EB2025	115-0520

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PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

kepco inc. ® REPLACEMENT PARTS LIST

MAIN CHASSIS, ASS'Y A2, MODEL KS120-1(M) Code 2-868

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
FRONT PANEL ASSEMBLY INCLUDES:				
DS101,102	2	Pilot Light Assembly	Drake Mfg. 7-503	152-0071
F101	1	Fuse, Slo Blo 5 A	Bussman MDA-5	141-0056
F102	1	Fuse, Slo Blo 1 A	Bussman MDL-1	141-0047
*M101	1	Meter, DC Voltmeter 0-120 V DC	General Electric DW91	135-0329
*M102	1	Meter, DC Ammeter 0-1.0 A DC	General Electric 8DW91A223BM2	135-0169
R101	1	Resistor, Variable 12.5 K ohm, 5 W, 10 Turn	Bourns 3507 Series	115-1832
R102	1	Resistor, Variable 100 ohm, 10 Turn, WW	Bourns 3507S-314-101	115-1447
S101	1	Switch, Toggle, SPST	Carling Electric AA252-63XKEP2	127-0107

*Metered Models Only.

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MAIN CHASSIS, ASS'Y A2, MODEL KS120-1(M) Code 2-868

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
B201	1	Motor	Barber Colman DYAF 761-110	148-0007
C201	1	Capacitor, Electrolytic, Can 4.2 K μF, 250 V	General Electric 43F3372MA3	117-0507
C202	1	Capacitor, Electrolytic, Can 1.1 K μF, 210 V	General Electric 43F1558C	117-0283
C203	1	Capacitor, Electrolytic, Pigtail 50 μF, 150 V	Industrial Cond. 10B936	117-0127
C204	1	Capacitor, Mylar, Pigtail 0.1 μF, 1 K V, 10%	Wesco Type 33M	117-0574
C205	1	Capacitor, Electrolytic, Can 130 μF, 300 V	General Electric 86F216E	117-0547
C207	1	Capacitor, Ceramic 0.005 μF, 2 K V	Sprague 20HKB-D5	117-0079
C209, 210	2	Capacitor, Electrolytic, Pigtail 1 K μF, 6 V	General Electric 43F7957AA1	117-0346
	1	Rectifier Assembly Includes the following:	Kepco Inc.	124-0300
CR201, 202	2	Rectifier, Silicon, Pigtail	Semicon SM 140/S	124-0028
CR203, 204	2	Rectifier, Silicon	Mallory 1N3211	124-0164
CR205, 206	2	Rectifier, Silicon	General Electric C30C	124-0277
R216, 217	2	Resistor, Fixed, Molded 220 ohm, 1/2 W, 10%	Allen Bradley EB2211	115-0371
R201	1	Resistor, Fixed, Power, Strip 50 ohm, 10 W	Hardwick Hindle B354	115-0865
R202	1	Resistor, Fixed, Power, Strip 2 K ohm, 20 W, 5%	Hardwick Hindle Type 1BRM-37	115-2031
R203	1	Resistor, Fixed, Power, Strip 5 K ohm, 10 W, 5%	Ward Leonard 10S5000	115-1719
R204	1	Resistor, Fixed, Power, Strip 200 ohm, 10 W, 5%	Hardwick Hindle 3/4 BRS53B-200	115-1268
R205	1	Resistor, Fixed, Precision 1 ohm, 50 W, 1%	Tepro TM-50W	115-1915

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MAIN CHASSIS, ASS'Y A2, MODEL KS120-1(M) Code 8-1166

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R208	1	Resistor, Fixed, Power, Strip 3.5 K ohm, 20 W, 5%	Hardwick Hindle Type 1BRM-37	115-2030
R209	1	Resistor, Variable 50 K ohm, 2 W	Allen Bradley JA1L040S503UZ	115-0437
R210	1	Resistor, Fixed, Molded 27 K ohm, 1/2 W, 10%	Allen Bradley EB2731	115-0262
*R211	1	Resistor, Fixed, Molded 120 K ohm, 1 W, 5%	Allen Bradley GB1245	115-0119
T201	1	Transformer	Kepco Magnetics	100-1551

*Un-metered Models Only.

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kepco inc. ® REPLACEMENT PARTS LIST

SCR CONTROL BOARD, PCB#2, ASS'Y A3, MODEL KS 120-1(M) Code 2-868

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C303,311	2	Capacitor,Mylar,Pigtail 0.05 μF, 200 V, 10%	TRW X663F	117-0362
C305,314	2	Capacitor,Mylar,Pigtail 0.2 μF, 200 V, 10%	TRW Type X663F	117-0236
C306	1	Capacitor,Mylar,Pigtail 0.1 μF, 200 V, 10%	Sprague 192P10492	117-0363
C307,310	2	Capacitor,Mylar,Pigtail 0.5 μF, 200 V, 10%	TRW Type X663F	117-0123
C312	1	Capacitor,Mylar,Pigtail 1 μF, 200 V, 10%	Wesco 33MM	117-0207
C313	1	Capacitor,Mylar,Pigtail 0.4 μF, 200 V, 10%	Wesco 33MM	117-0128
C315	1	Capacitor,Mylar,Pigtail 0.02 μF, 200 V, 10%	Sprague 192P20392	117-0377
CR306	1	Rectifier,Silicon,Pigtail	Semicon SM 140/S	124-0028
CR307	1	Zener Diode	IRC AN267	121-0028
CR308	1	Zener Diode	Motorola 1N3026B	121-0036
CR309,310	2	Rectifier,Silicon,Pigtail	Semicon SM110	124-0133
Q301	1	Transistor,Silicon,NPN	General Electric 2N336A	119-0056
Q302	1	Transistor,Silicon,Unijunction	General Electric 2N1671A	119-0048
Q303,304	2	Transistor,Silicon,PNP	Hughes 2N1131A	119-0055
R302	1	Resistor,Fixed,Molded 10 K ohm, 1 W, 10%	Allen Bradley GB1031	115-0040
R303	1	Resistor,Fixed,Power,Axial 5 K ohm, 3 W, 5%	Hardwick Hindle 9/16 GA-5000 LTC	115-1094
R306	1	Resistor,Fixed,Molded 6.8 K ohm, 1/2 W, 5%	Allen Bradley EB6825	115-0579
R307	1	Resistor,Fixed,Power,Axial 2 K ohm, 5 W, 5%	Tepro TS5W	115-0568
R308	1	Resistor,Fixed,Molded 470 ohm, 1/2 W, 10%	Allen Bradley EB4711	115-0608
R309	1	Resistor,Fixed,Molded 390 ohm, 1/2 W, 5%	Allen Bradley EB3905	115-0883

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

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REPLACEMENT PARTS LIST

SCR CONTROL BOARD, PCB#2, ASS'Y A3, MODEL KS 120-1(M) Code 2-868

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R310	1	Resistor, Fixed, Molded 3.3 K ohm, 1/2 W, 10%	Allen Bradley EB3321	115-0439
R312	1	Resistor, Fixed, Molded 1.5 K ohm, 1/2 W, 5%	Allen Bradley EB1525	115-0442
R313, 314	2	Resistor, Fixed, Molded 10 K ohm, 1/2 W, 10%	Allen Bradley EB1031	115-0489
R318	1	Resistor, Fixed, Molded 10 ohm, 1/2 W, 10%	Allen Bradley EB1001	115-0502
R319	1	Resistor, Fixed, Molded 1 K ohm, 1/2 W, 10%	Allen Bradley EB1021	115-0547
R320	1	Resistor, Fixed, Molded 8.2 K ohm, 1/2 W, 10%	Allen Bradley EB8221	115-1169
R322	1	Resistor, Variable 100 K ohm, 1/2 W, 30%	Beckman 62PR100K	115-2054
R323	1	Resistor, Fixed, Molded 180 K ohm, 1/2 W, 5%	Allen Bradley EB1835	115-0272
R324	1	Resistor, Fixed, Molded 330 K ohm, 1/2 W, 5%	Allen Bradley EB3335	115-0250
R325	1	Resistor, Fixed, Molded 13 K ohm, 1/2 W, 5%	Allen Bradley EB1325	115-0920
R326, 328	2	Resistor, Fixed, Precision 1.1 K ohm, 1 W, 1%	IRC CES Type	115-1860
R327	1	Resistor, Variable 3 K ohm, 1/2 W, 10%	Bourns 3067P-1-302	115-1668

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

REPLACEMENT PARTS LIST

REFERENCE BOARD ASSEMBLY, PCB#3, ASS'Y A5, MODEL KS120-1(M) Code 6-2866

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C501	1	Capacitor, Electrolytic, Pigtail 20 µF, 150 V	General Electric 43F2271AA2	117-0145
C502	1	Capacitor, Electrolytic, Pigtail 1000 µF, 10 V	General Electric 43F2381AA2	117-0176
C503	1	Capacitor, Electrolytic, Pigtail 150 µF, 75 V	General Electric 43F7147AA1	117-0388
C504, 505	2	Capacitor, Electrolytic, Pigtail 22 µF, 25 V	General Electric 76F02KE220	117-0503
C506	1	Capacitor, Electrolytic, Pigtail 500 µF, 50 V	General Electric 43F2528AA1	117-0221
CR501, 503, 504	3	Rectifier, Silicon, Pigtail	Semicon SM 140/S	124-0028
CR502, 505, 506, 508, 509, 510	6	Rectifier, Silicon, Pigtail	Semicon SM 110	124-0133
CR507	1	Zener Diode	Hoffman 1N1773	121-0012
K501	1	Relay 3P DT	Omega 200 PC 3CX	140-0040
R501	1	Resistor, Fixed, Molded 100 K ohm, 1/2 W, 10%	Allen Bradley EB1041	115-0809
R502	1	Resistor, Fixed, Power, Axial 1 K ohm, 5 W, 5%	Tepro TS5W	115-0512
R503	1	Resistor, Fixed, Power, Axial 2.5 K ohm, 3 W, 5%	Hardwick Hindle 742	115-0469
R504	1	Resistor, Fixed, Molded 47 ohm, 1/2 W, 10%	Allen Bradley EB4701	115-0718
R505	1	Resistor, Fixed, Power, Axial 2 K ohm, 5 W, 5%	Tepro TS5W	115-0568
T501	1	Transformer	Kepco Magnetics	100-1543

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kepco inc. ® REPLACEMENT PARTS LIST

PLUG - IN ASSEMBLY A6, MODEL KS120-1(M) Code 8-1166

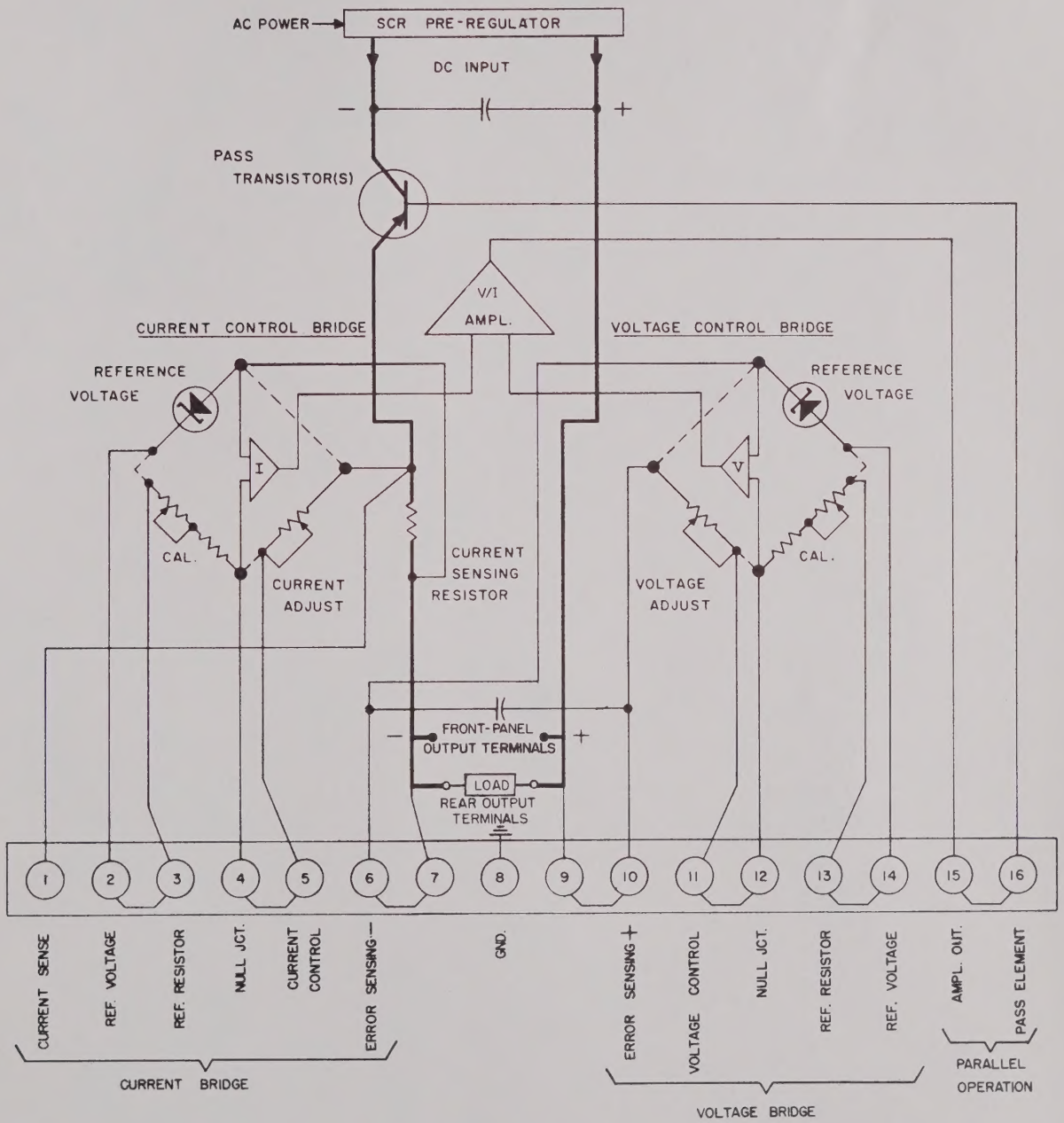
SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
A6	1	Pass Assembly Includes the following:	Kepco Inc.	110-0240
Q601,602, 603,604	4	Transistor,PNP	Delco 2N174	119-0016
Q605,606, 607,608	4	Transistor,PNP	RCA TA 2651	119-0074
CR601,602, 603	3	Zener Diode	Hoffman 1N1766	121-0021
R601,602, 603,604	4	Resistor,Fixed,Power,Axial 30 K ohm, 5 W, 5%	Sprague 27E-30K	115-0652
R605	1	Resistor,Fixed,Molded 100 ohm, 1/2 W, 10%	Allen Bradley EB1011	115-0626
R606	1	Resistor,Fixed,Molded 220 K ohm, 1/2 W, 5%	Allen Bradley EB2245	115-0261
R607,609, 610	3	Resistor,Fixed,Power,Axial 1 K ohm, 3 W, 5%	Tepro TS3C	115-1302
R608,611, 612	3	Resistor,Fixed,Power,Axial 1.2 K ohm, 3 W, 5%	Hardwick Hindle 736	115-1071
S601	1	Switch,Thermostatic,73°C	Chatham Controls DRSCORP73C	127-0093

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

SIMPLIFIED DIAGRAM OF MODEL KS AUTO-CROSSOVER POWER SUPPLY

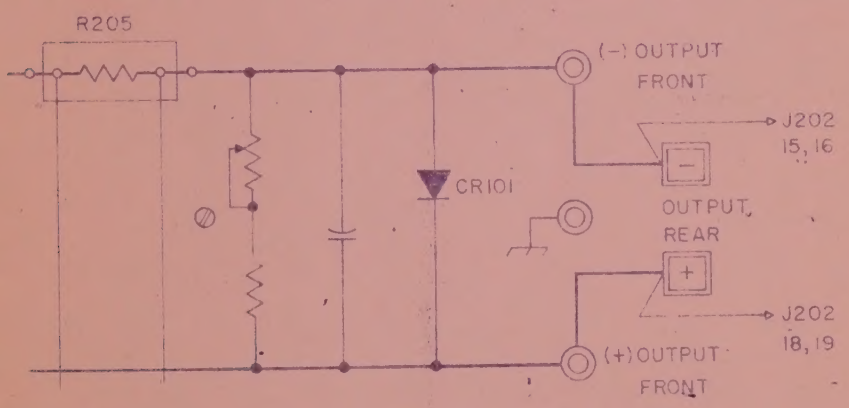
WITH REAR TERMINAL CONNECTION DETAIL



INSTRUCTION MANUAL CORRECTION

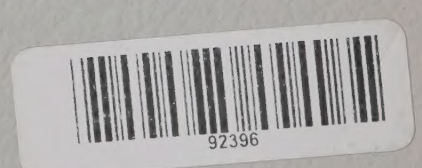
Please note the following corrections to the Manual Material as indicated:
Parts List & Schematic Diagram:

1. Change R312 Resistor, Fixed, Molded 1.5 K ohm, 1/2 W, 5% Kepco #115-0442 to:
   R312 Resistor, Fixed, Molded 750 ohm, 1/2 W, 5% Kepco #115-0566.
2. Change R320 Resistor, Fixed, Molded 8.2 K ohm, 1/2 W, 10% Kepco #115-1169 to:
   R320 Resistor, Fixed, Molded 3.9 K ohm, 1/2 W, 5% Kepco #115-0808.
3. Change R325 Resistor, Fixed, Molded 13 K ohm, 1/2 W, 5% Kepco #115-0920 to:
   R325 Resistor, Fixed, Molded 22 K ohm, 1/2 W, 10% Kepco #115-0260.
4. Change C303 Capacitor, Mylar, Pigtail 0.05 µF, 200 V, 10% Kepco #117-0362 to:
   C303 Capacitor, Mylar, Pigtail 0.02 µF, 200 V, 10% Kepco #117-0377.
5. Change C311 Capacitor, Mylar, Pigtail 0.05 µF, 200 V, 10% Kepco #117-0362 to:
   C311 Capacitor, Mylar, Pigtail 0.1 µF, 200 V, 10% Kepco #117-0363.
6. Change C307 Capacitor, Mylar, Pigtail 0.5 µF, 200 V, 10% Kepco #117-0123 to:
   C307 Capacitor, Mylar, Pigtail 1 µF, 200 V, 10% Kepco #117-0207.
7. Delete C310 Capacitor, Mylar, Pigtail 0.5 µF, 200 V, 10% Kepco #117-0123.
8. Add CR 101 Rectifier, Silicon, Pigtail Kepco #124-0133.
   (See Fig. below for schematic location)
9. Delete CR 310 Rectifier, Silicon, Pigtail Kepco #124-0133.



10. Change manufacturer and jetec number of all (PNP) 2n1131A HUGHES to:
    (PNP) 2N1132 TRANSITRON.

KS 120-1(M)/9-268/r5



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